Tales from a Troubled Marriage: Science and Law in Environmental Policy

Oliver Houck

1st generation environmental law

- science embraced, but
- how much biological impact is okay?
- how much uncertainty is okay?
- failure

The scientific debate remains open. Voters believe there is no consensus about global warming within the scientific community. Should the public come to believe that the scientific issues are settled, their views will change accordingly. Therefore, you need to continue to make the lack of scientific certainty the primary issue in the debate. [Frank Luntz, political strategist, 2002]

2nd generation environmental law

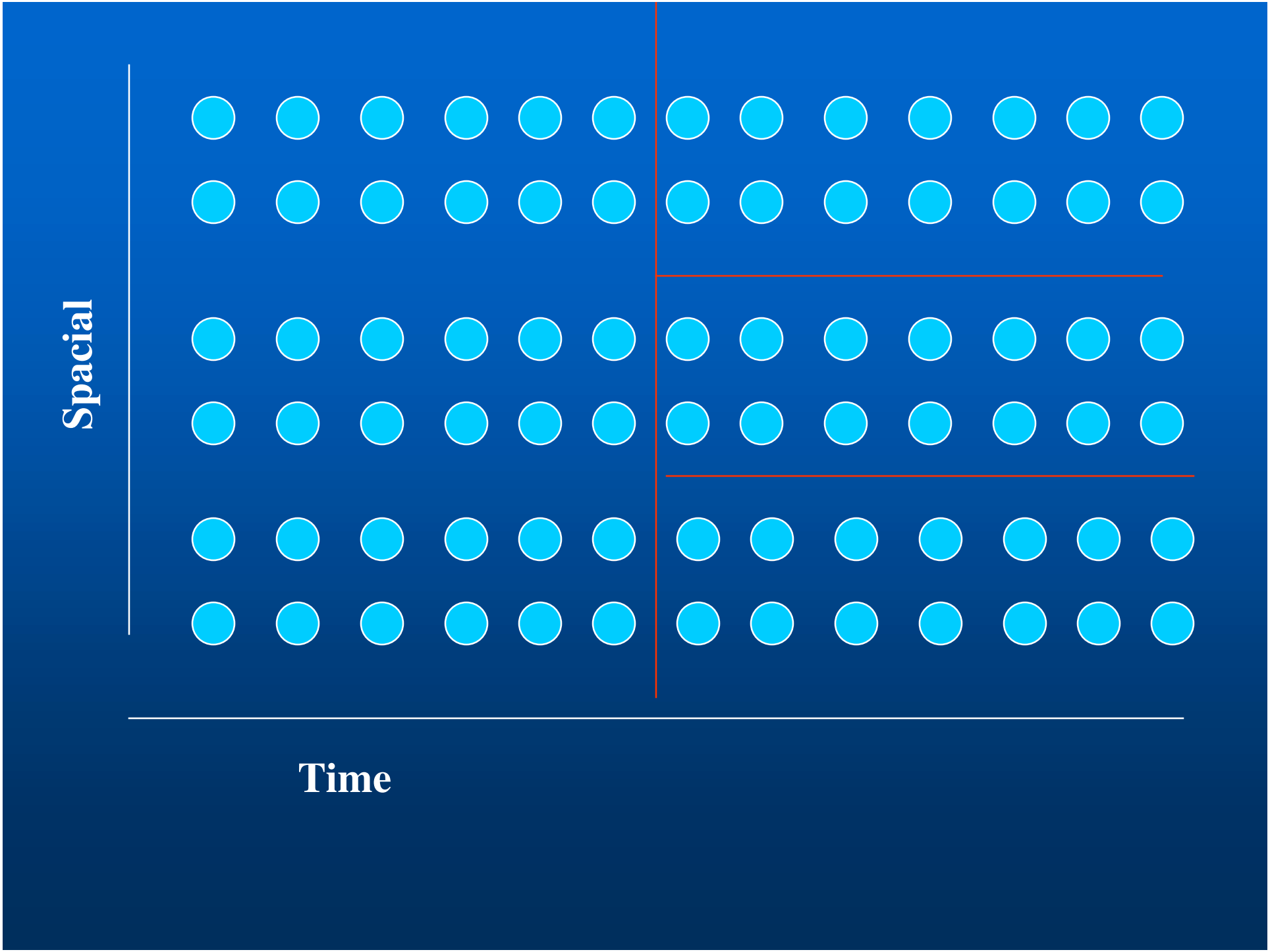
- technology standards
- science used to justify the need for the standard

Four Cautionary Tales

- Return to scientific management
  - Industry argues against technology-based limits, back to site-specific "science"
- Good science
  - The evidence that supports one's position
- Money
  - Are scientists above the lure of money?
- Play it safe
  - Just monitor
  - Or, just argue: Dr. Porter's buttermilk experiment

Studies/Monitoring

- Dumb studies (common)
  - No specific questions
    - No peer review up front
  - No ability to detect changes due to X
    - Leads to false conclusions
  - Political monitoring
    - Entrenched perceptions
    - Monitoring instead of acting


Spacial
Time

Studies/Monitoring

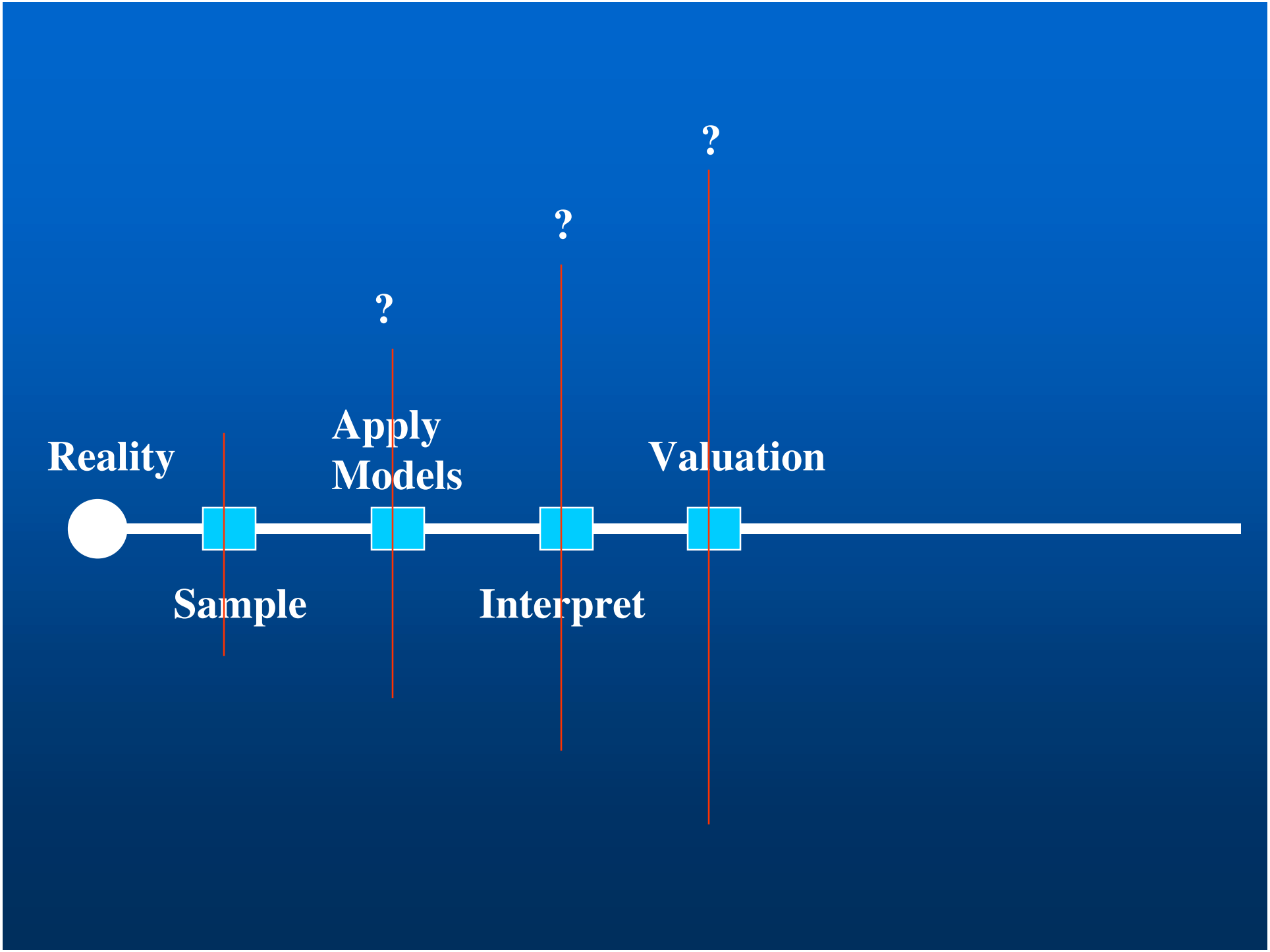
- Smart studies/monitoring
  - Specific questions about issues you intend to act on
    - Consider results and follow-up actions
    - Peer review up front (questions and design)
    - Define ability to detect changes
  - Example for discharge monitoring:
    - BACI
    - If not BACI, then what?

Entrainment Studies: a special case

- **Five Very Difficult and Extraordinarily Contentious Issues**
  - Determining species that are entrained (many are larval forms)
  - Estimating the true numbers entrained
  - Assessing the ecological effects of entrainment loss, particularly the use and interpretation of models
  - Converting technical estimations of impact into a currency that lay-people can understand
  - Addressing the impact: technology and mitigation
    - Impacts that were not estimated

Why do entrainment or thermal studies?

To define impacts (changes) caused by the power plant… with some degree of confidence… and act on them


?
?
?
Reality
Apply
Models
Valuation
Sample
Interpret

Examples

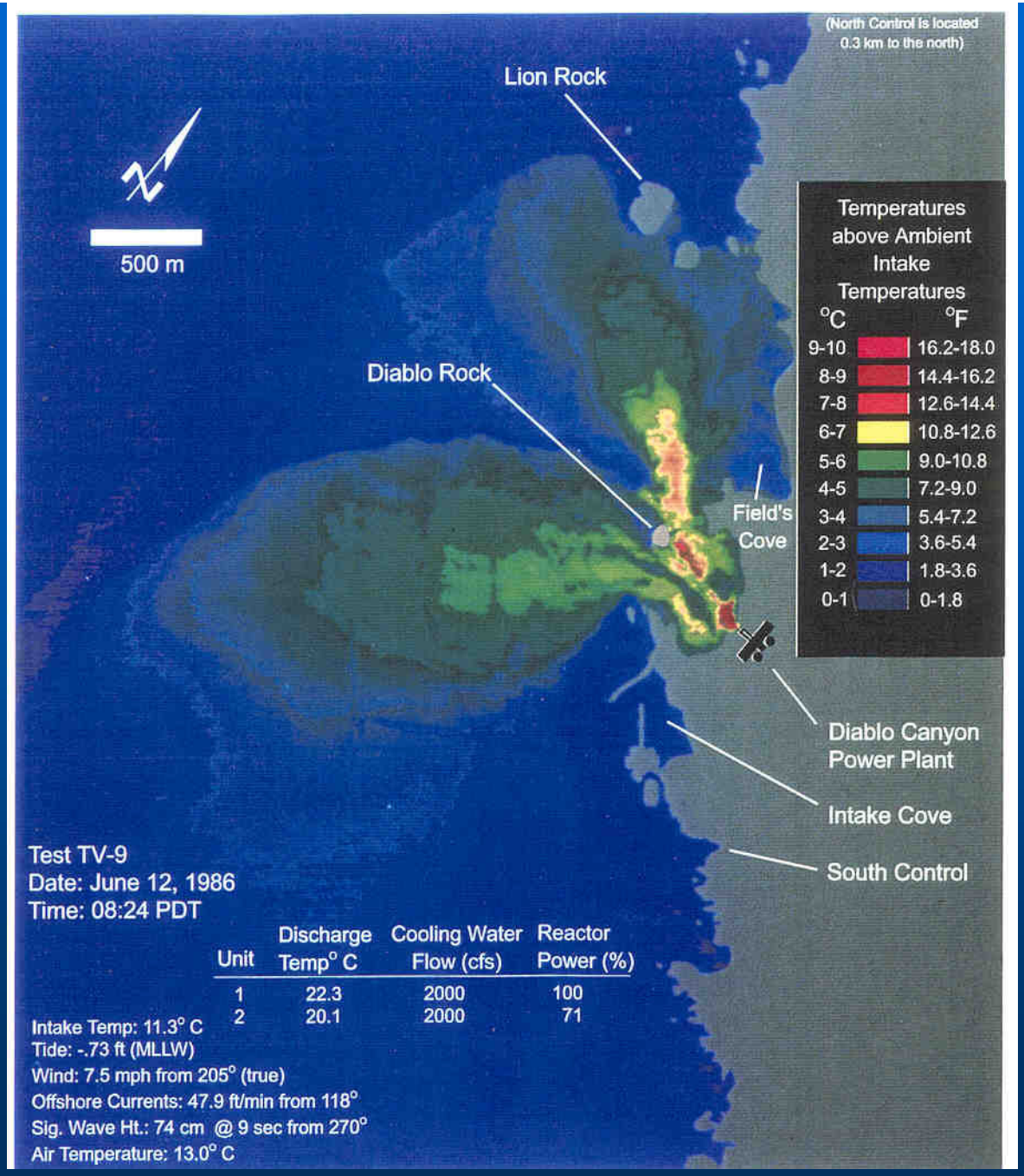
- Diablo Canyon Nuclear Power Plant
  - 2,500 MGD (2.5 BGD)
- Morro Bay Power Plant
  - 688 MGD (0.688 BGD)
- Moss Landing Power Plant
  - 1,200 MGD (1.2 BGD)

Central Coast Power Plants

Independent Members of the Technical Work Group (TWG)

- Entrainment
  - Allan Stewart-Oaten, Professor UCSB
  - Roger Nisbet, Professor UCSB
  - Pete Raimondi, Professor UCSC
  - Gregor Calliet, Professor MLML
- Thermal
  - Michael Foster, Professor MLML
  - David Schiel, Professor University of Canterbury
- Help from several others
- Tenera Environmental conducted all work


Thermal Effects:
Predictions versus Actual Impacts



Predicted vs. Actual

BACI

Thermal Effects

- ~1 mile of intertidal habitat degraded
- ~50 acres of subtidal effects

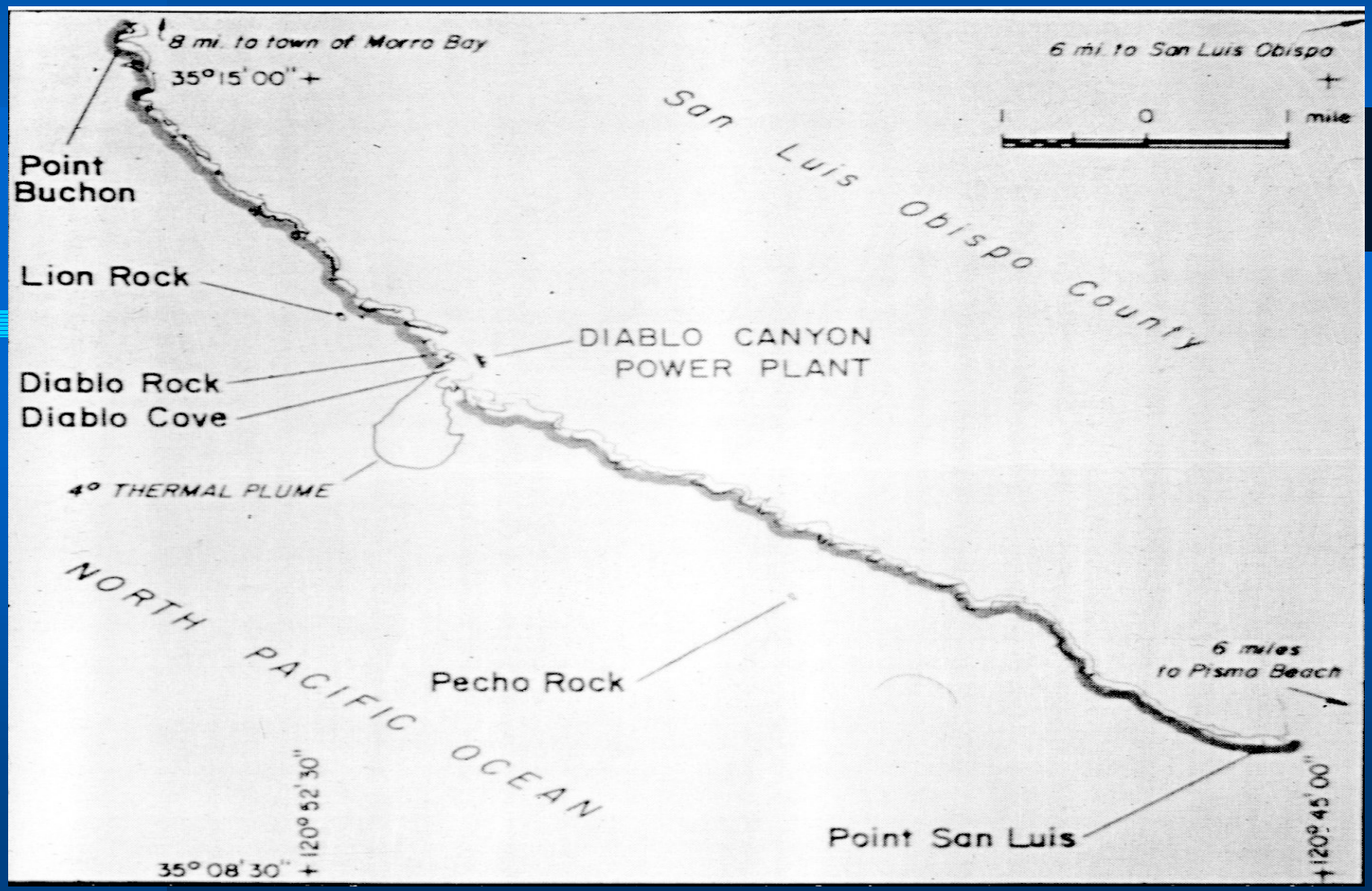
- Offshore discharge structure
  - No precedent for this setting
  - $400 million+
  - Major construction impacts
  - Transfers impacts to offshore reefs

Thermal Discharge Impacts

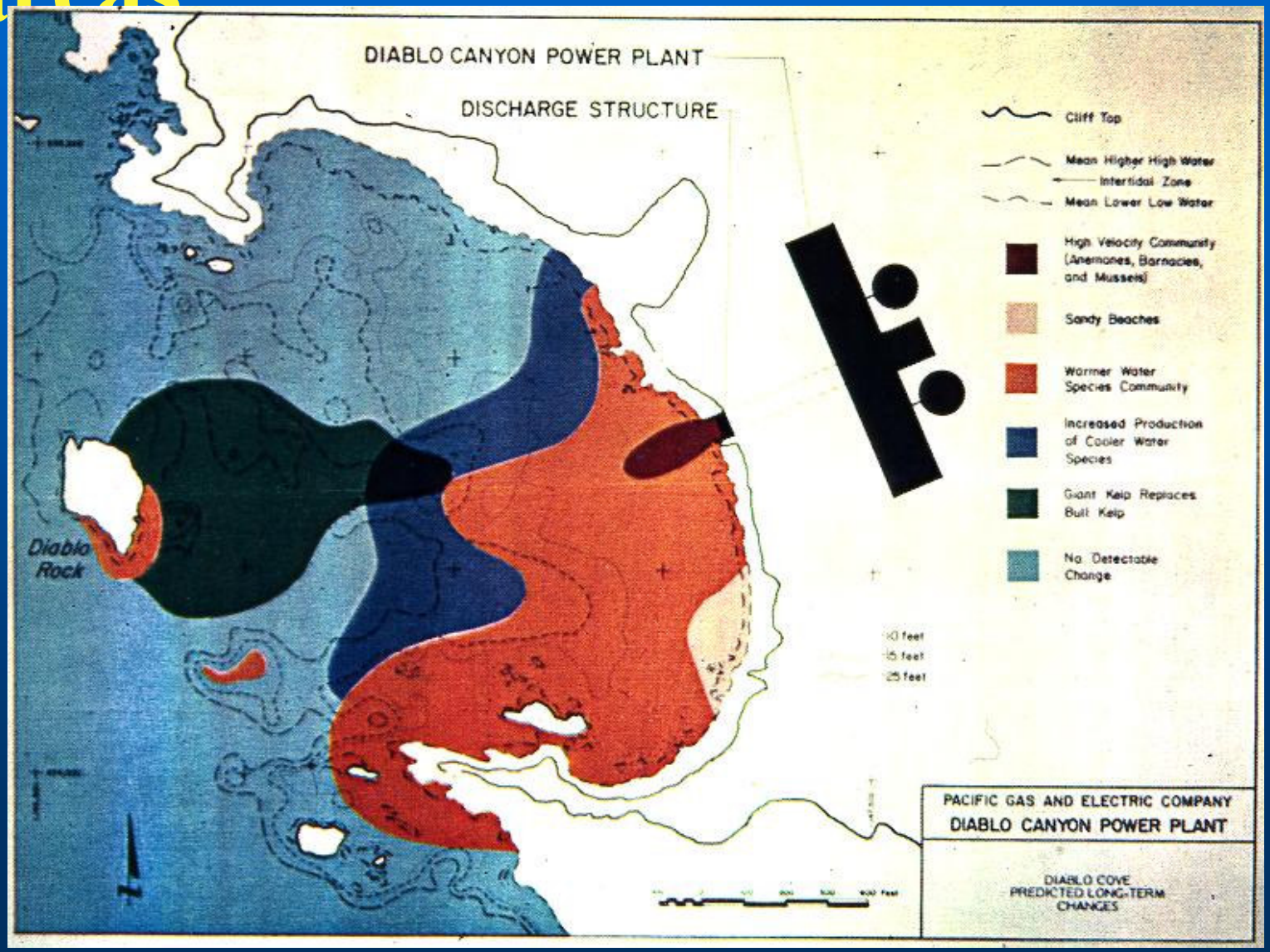
- Magnitude of taxa impacts
- Spatial extent of impacts

Diablo Cove

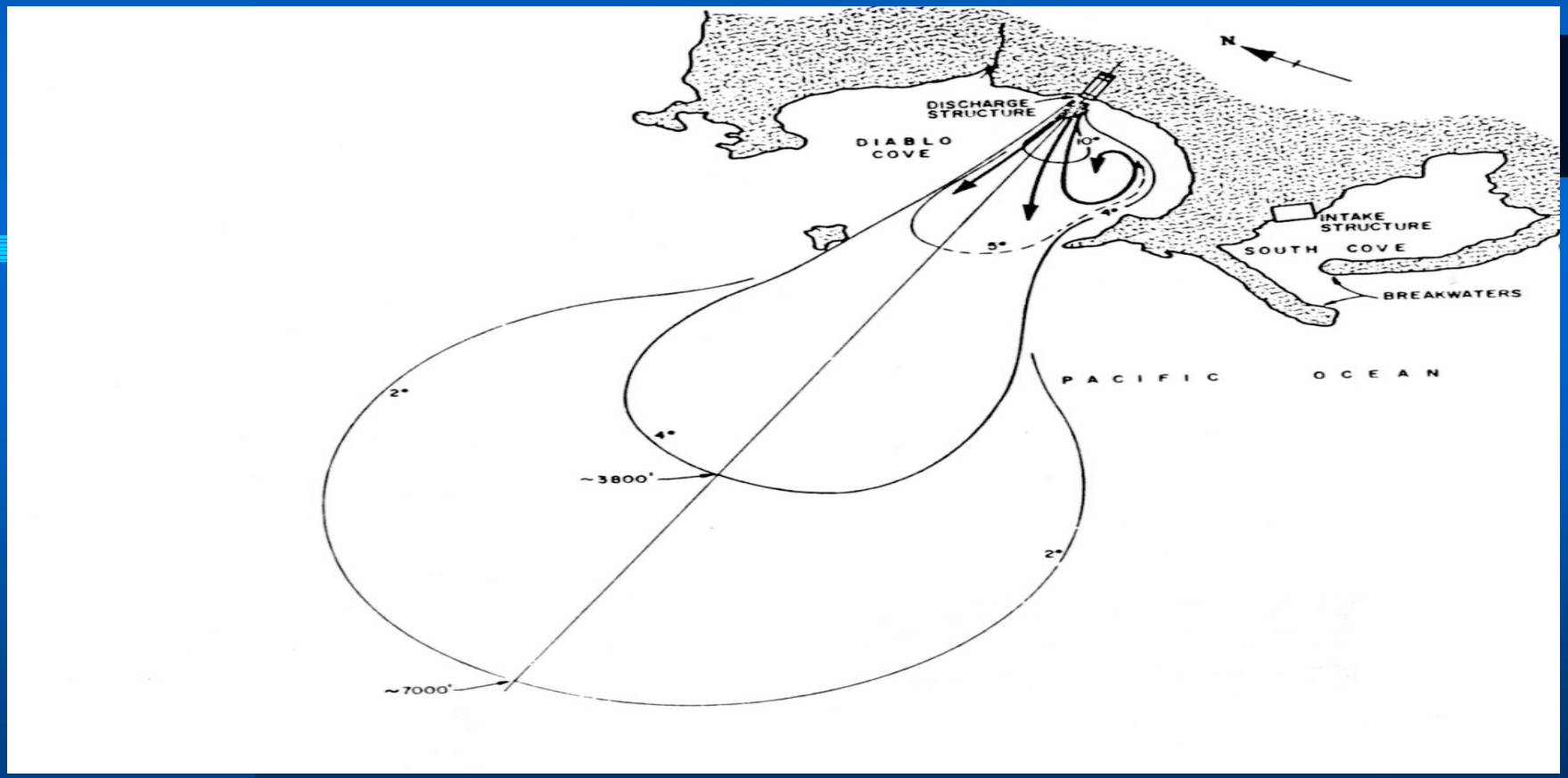
Plume Prediction from PG&E's 1982 Thermal Report



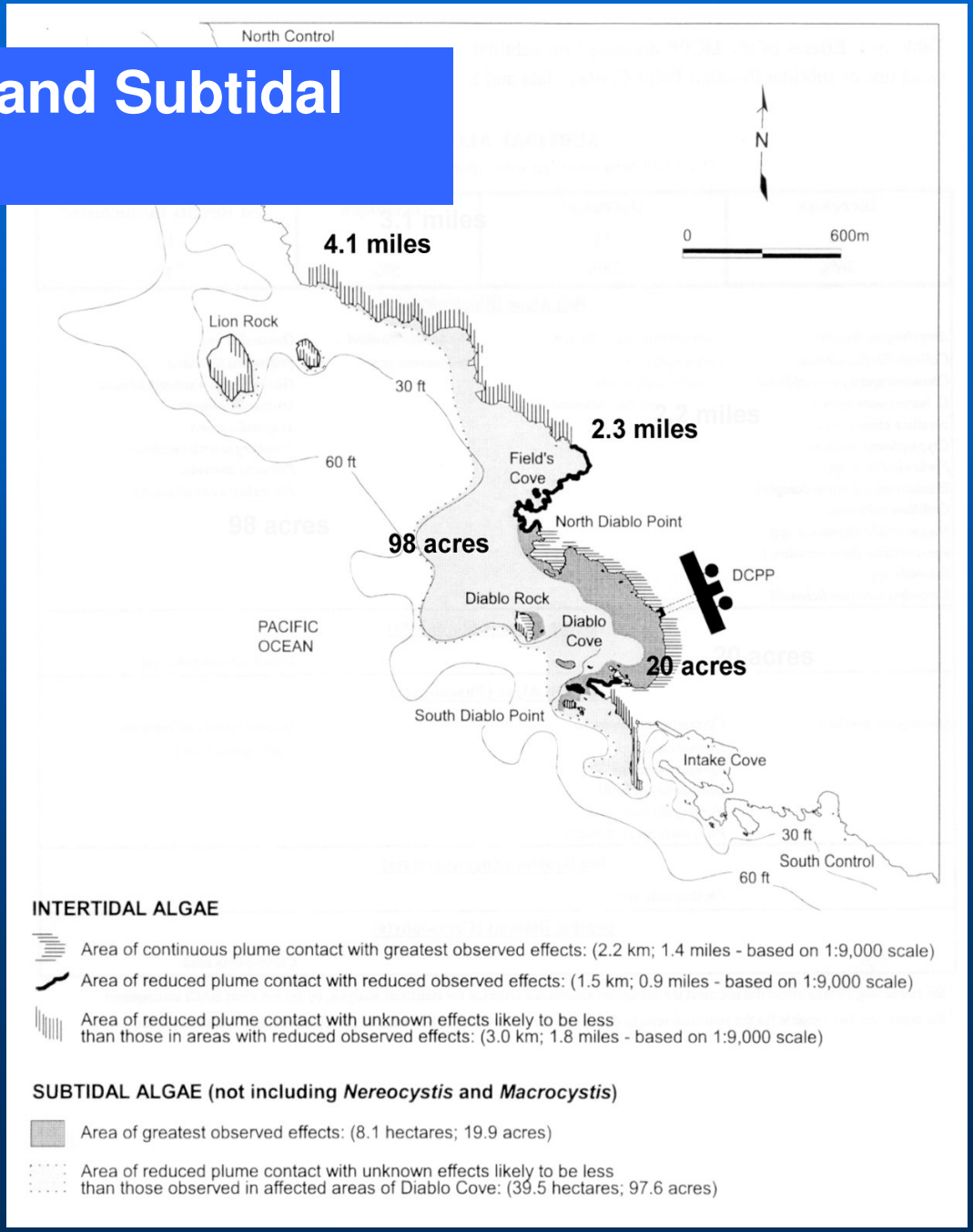
Predicted intertidal impact areas



Original Plume Prediction from the 1973 Environmental Statement



Intertidal and Subtidal ALGAE



INTERTIDAL ALGAE

mean %cover in Diablo Cove (1.4 miles of habitat)

- Sixteen species decreased between 50% and 99%
- Ten of the sixteen species decreased at least 80%
- Five of the sixteen species decreased at least 90%
- Total algal cover decreased from 62% to 18% (-70% relative to controls)
- Bare rock substrate increased over 100%

SUBTIDAL ALGAE

Diablo Cove 40 acres

Impacts possible up to 117 acres

- Eight species decreased at least 60% percent
- Four species decreased at least 80%
- Three species decreased at least 90%
- Major reduction in subtidal kelps

b) Diablo Cove - Kelps: mean no. individuals per 7m²

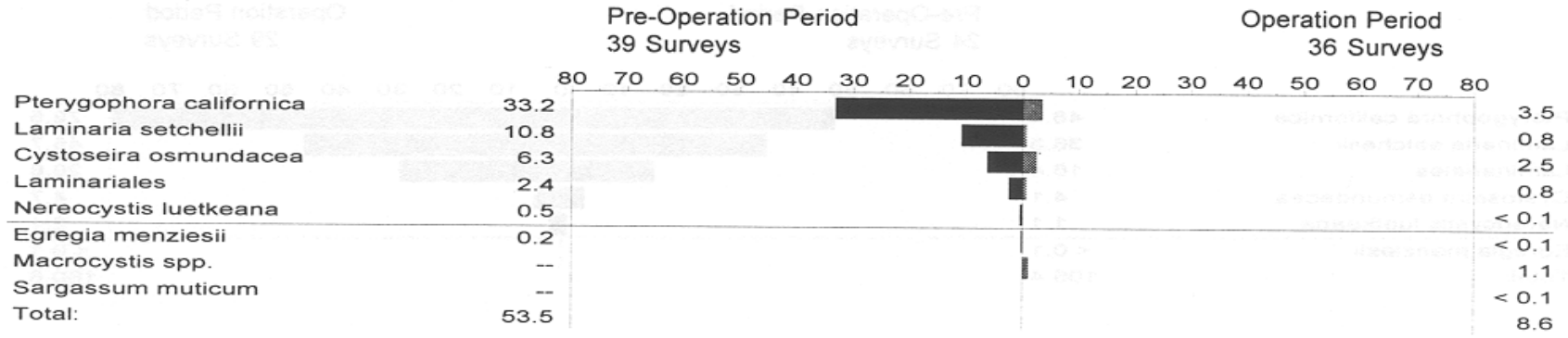


Figure 4-4. Algal abundances at the Diablo Cove subtidal benthic stations. (a) Understory algae mean percent cover sampled by the SLC method. (b) Kelp mean counts/7m² sampled by the SAQ method.

b) South Control - Kelps: mean no. individuals per 7m²

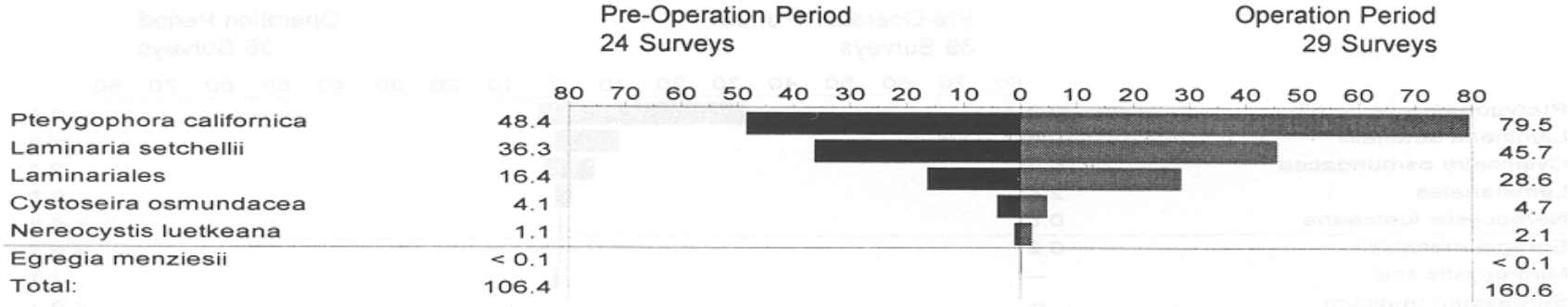
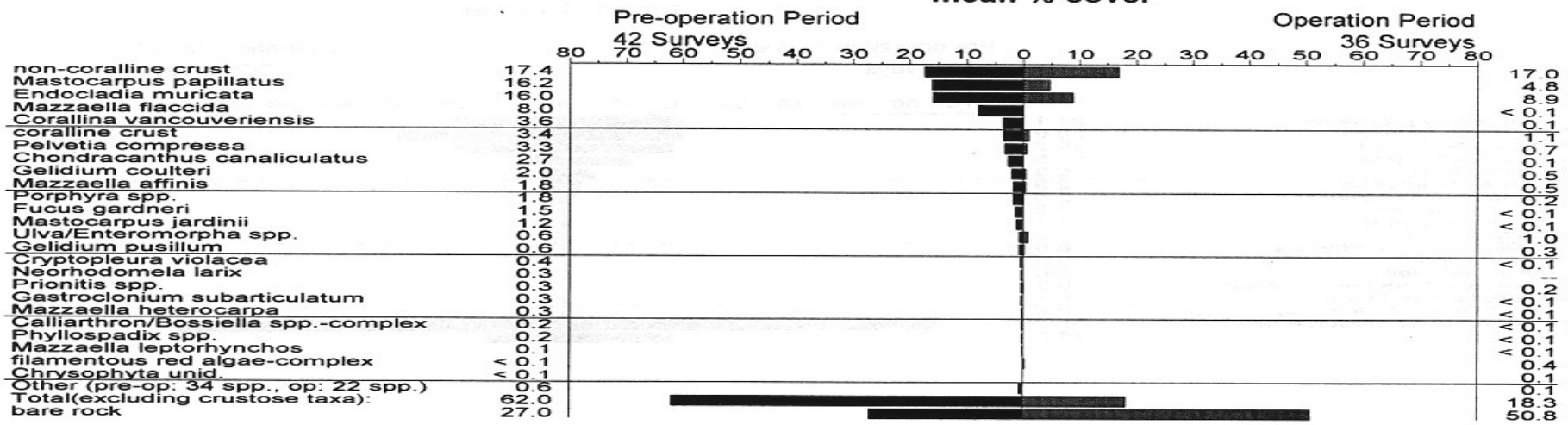


Figure 4-5. Algal abundances at the South Control subtidal benthic stations. (a) Understory algae mean percent cover sampled by the SLC method. (b) Kelp mean counts/7m² sampled by the SAQ method.

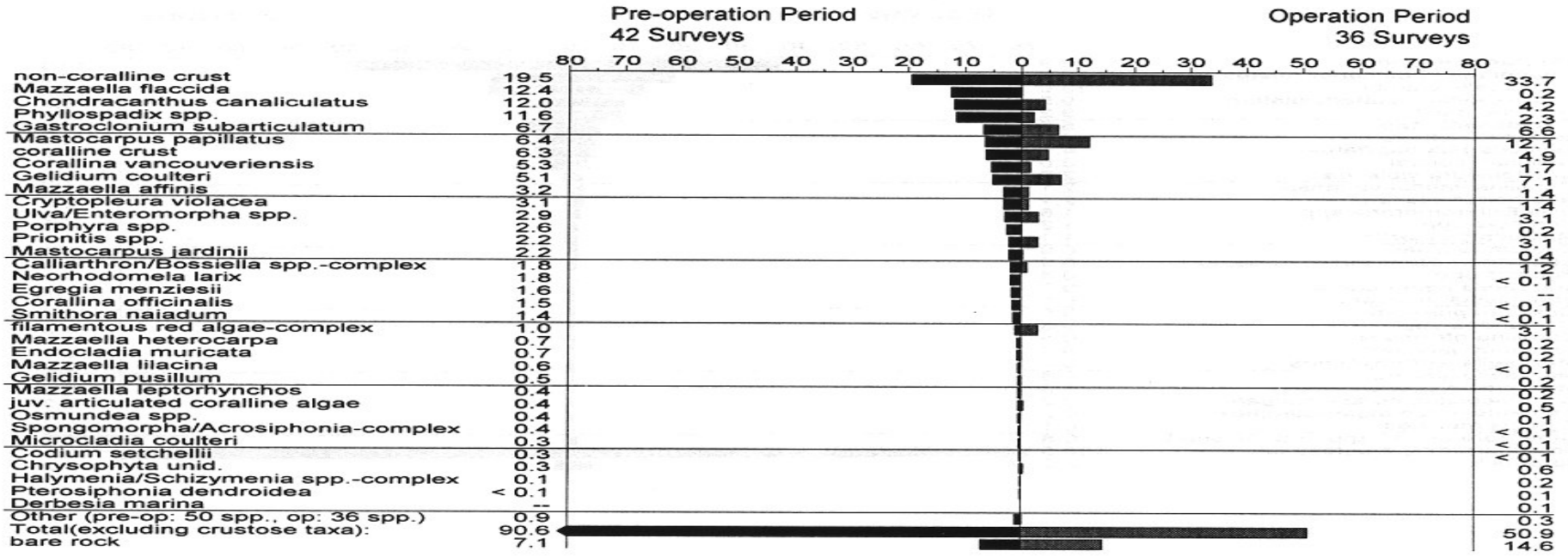
a) Diablo Cove +0.9 m MLLW Transects

mean % cover



	Pre-op	Op
non-coralline crust	17.4	17.0
Mastocarpus papillatus	16.2	4.8
Endocladia muricata	16.0	8.9
Mazzaella flaccida	8.0	< 0.1
Corallina vancouveriensis	3.6	0.1
coralline crust	3.4	1.1
Pelvetia compressa	3.3	0.7
Chondracanthus canaliculatus	2.7	0.1
Gelidium coulteri	2.0	0.5
Mazzaella affinis	1.8	0.5
Porphyra spp.	1.8	0.2
Fucus gardneri	1.5	< 0.1
Mastocarpus jardinii	1.2	< 0.1
Ulva/Enteromorpha spp.	0.6	1.0
Gelidium pusillum	0.6	0.3
Cryptopleura violacea	0.4	< 0.1
Neorhodomela larix	0.3	--
Prionitis spp.	0.3	0.2
Gastroclonium subarticulatum	0.3	< 0.1
Mazzaella heterocarpa	0.3	< 0.1
Calliarthron/Bossiella spp.-complex	0.2	< 0.1
Phyllospadix spp.	0.2	< 0.1
Mazzaella leptorhynchos	0.1	< 0.1
filamentous red algae-complex	< 0.1	0.4
Chrysophyta unid.	< 0.1	0.1
Other (pre-op: 34 spp., op: 22 spp.)	0.6	0.1
Total(excluding crustose taxa):	62.0	18.3
bare rock	27.0	50.8

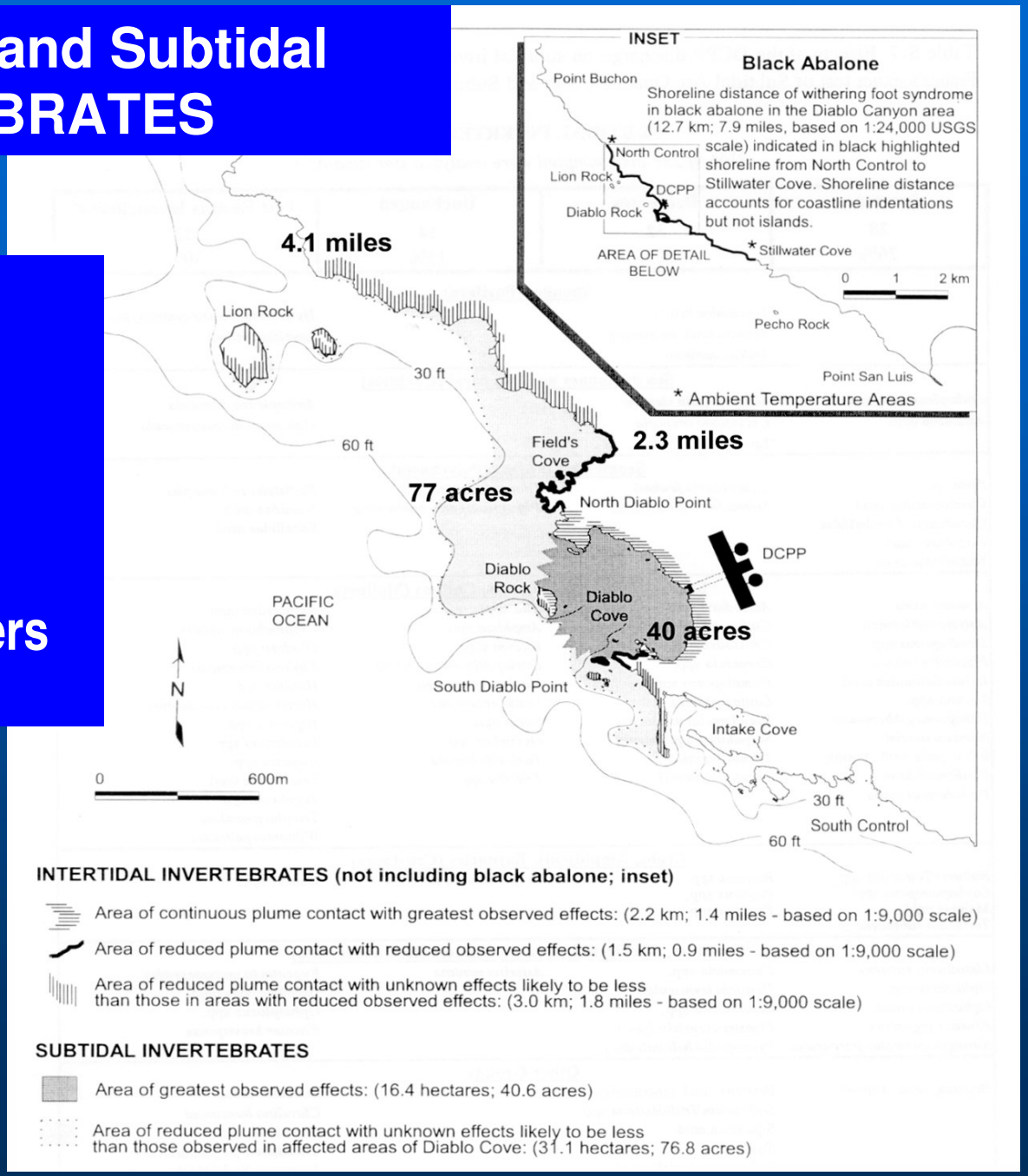
b) Diablo Cove +0.3 m MLLW Transects



	Pre-op	Op
non-coralline crust	19.5	33.7
Mazzaella flaccida	12.4	0.2
Chondracanthus canaliculatus	12.0	4.2
Phyllospadix spp.	11.6	2.3
Gastroclonium subarticulatum	6.7	6.6
Mastocarpus papillatus	6.4	12.1
coralline crust	6.3	4.9
Corallina vancouveriensis	5.3	1.7
Gelidium coulteri	5.1	7.1
Mazzaella affinis	3.2	1.4
Cryptopleura violacea	3.1	1.4
Ulva/Enteromorpha spp.	2.9	3.1
Porphyra spp.	2.6	0.2
Prionitis spp.	2.2	3.1
Mastocarpus jardinii	2.2	0.4
Calliarthron/Bossiella spp.-complex	1.8	1.2
Neorhodomela larix	1.8	< 0.1
Egregia menziesii	1.6	--
Corallina officinalis	1.5	< 0.1
Smithora naiadum	1.4	< 0.1
filamentous red algae-complex	1.0	3.1
Mazzaella heterocarpa	0.7	0.2
Endocladia muricata	0.7	0.2
Mazzaella lilacina	0.6	< 0.1
Gelidium pusillum	0.5	0.2
Mazzaella leptorhynchos	0.4	0.2
juv. articulated coralline algae	0.4	0.5
Osmundea spp.	0.4	0.1
Spongomorpha/Acrosiphonia-complex	0.4	< 0.1
Microcladia coulteri	0.3	< 0.1
Codium setchellii	0.3	< 0.1
Chrysophyta unid.	0.3	0.6
Halymenia/Schizymenia spp.-complex	0.1	0.2
Pterosiphonia dendroidea	< 0.1	0.1
Derbesia marina	--	0.1
Other (pre-op: 50 spp., op: 36 spp.)	0.9	0.3
Total(excluding crustose taxa):	90.6	50.9
bare rock	7.1	14.6

Intertidal and Subtidal INVERTEBRATES

- Sponges
- Snails
- Clams
- Crabs
- Sea Stars
- Sea Urchins
- Sea Cucumbers
- etc.



Intertidal Invertebrates

Diablo Cove (1.4 miles of habitat, effects detected up to 2.3 miles, effects possible up to 4.1 miles)

- Major reductions in many indigenous species, up to 99%
- major increases in other species, up several thousand %
- large percent changes in species abundance illustrate degradation of species, communities, and habitat

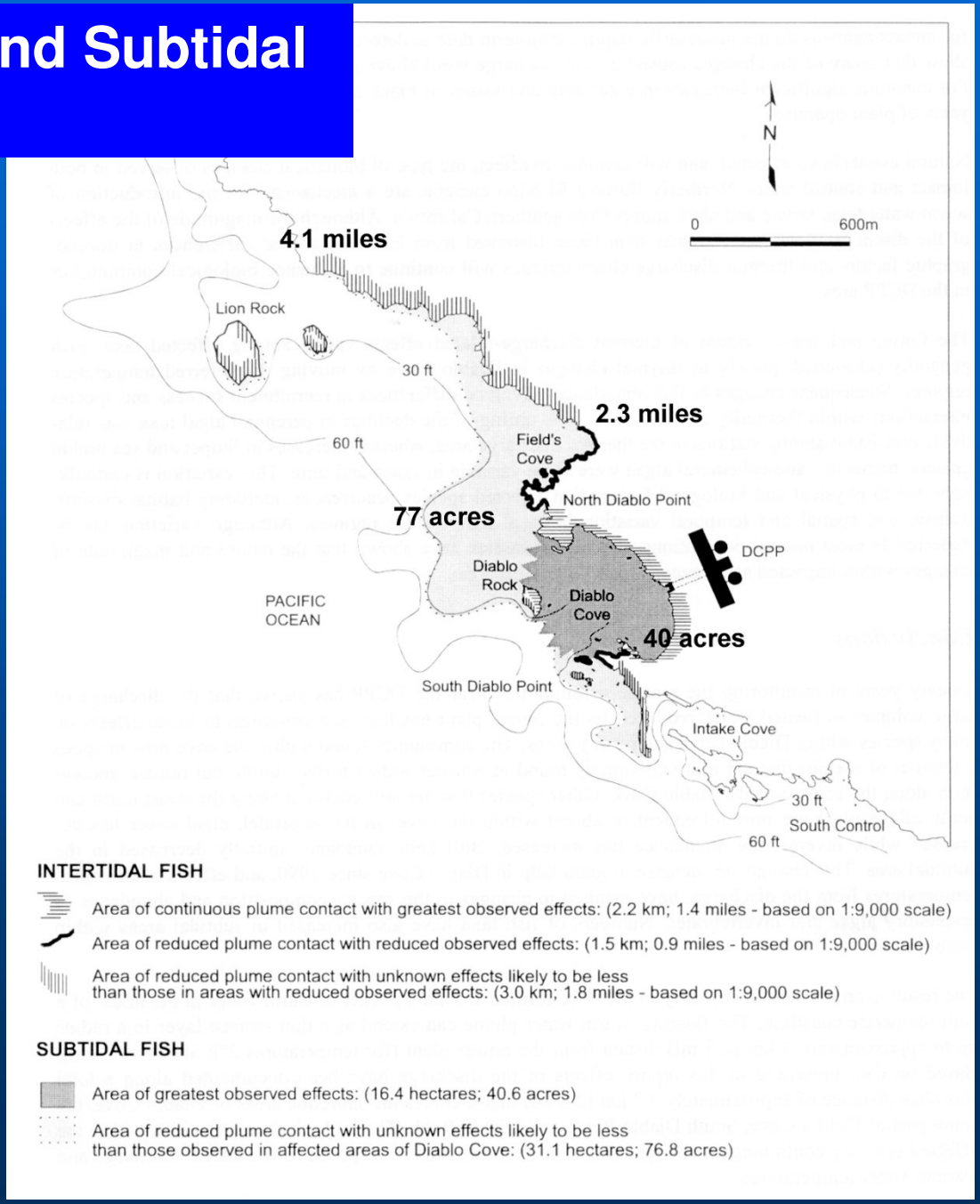
Subtidal Invertebrates

Diablo Cove- 40 acres

Effects possible up to 117 acres

- Major reductions in many indigenous species, up to 98%
- major increases in other species, up several thousand %
- large percent changes in species abundance illustrate degradation of species, communities, and habitat

Intertidal and Subtidal FISH

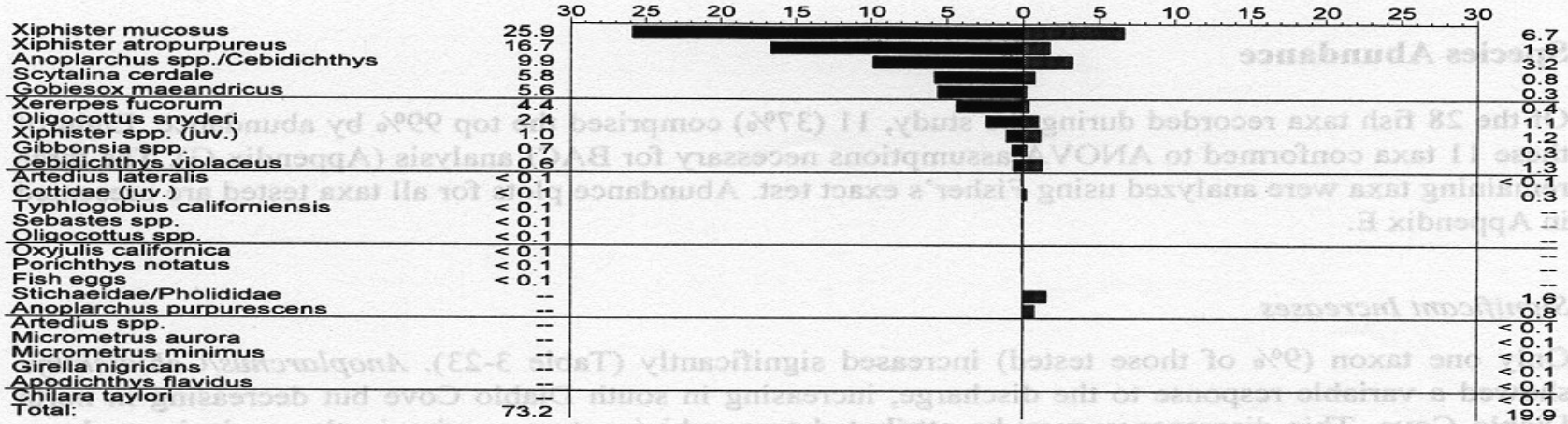


Fish

Intertidal: 1.4 miles, 2.3 miles, 4.1 miles
Subtidal: 40 acres in Diablo Cove, effects possible up to 117 acres

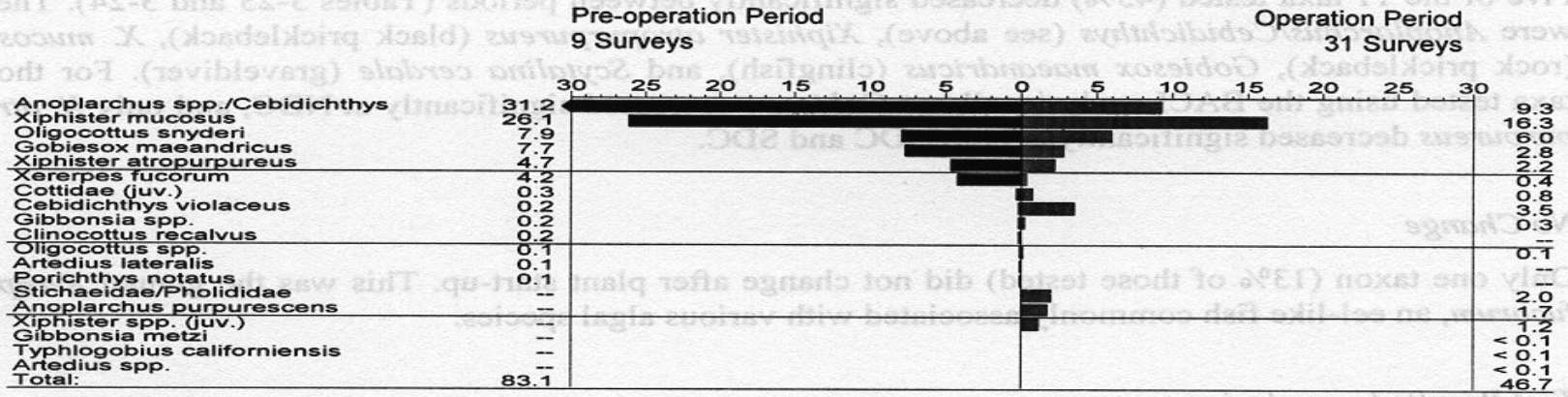
- Large % decreases among intertidal and subtidal fish
- Increases in pollution tolerant species (sharks, rays)

a) Diablo Cove Vertical Band Transect Stations
mean count per station



	Pre-operation Period (22 Surveys)	Operation Period (32 Surveys)
Xiphister mucosus	25.9	6.7
Xiphister atropurpureus	16.7	1.8
Anoplarchus spp./Cebidichthys	9.9	3.2
Scytalina cerdale	5.8	0.8
Gobiesox maeandricus	5.6	0.3
Xererpes fucorum	4.4	0.4
Oligocottus snyderi	2.4	1.1
Xiphister spp. (juv.)	1.0	1.2
Gibbonsia spp.	0.7	0.3
Cebidichthys violaceus	0.6	1.3
Artedius lateralis	< 0.1	< 0.1
Cottidae (juv.)	< 0.1	0.3
Typhlogobius californiensis	< 0.1	--
Sebastes spp.	< 0.1	--
Oligocottus spp.	< 0.1	--
Oxyjulis californica	< 0.1	--
Porichthys notatus	< 0.1	--
Fish eggs	< 0.1	--
Stichaeidae/Pholididae	--	1.6
Anoplarchus purpurescens	--	0.8
Artedius spp.	--	< 0.1
Micrometrus aurora	--	< 0.1
Micrometrus minimus	--	< 0.1
Girella nigricans	--	< 0.1
Apodichthys flavidus	--	< 0.1
Chilara taylori	--	< 0.1
Total:	73.2	19.9

b) Field's Cove Vertical Band Transect Station



	Pre-operation Period (9 Surveys)	Operation Period (31 Surveys)
Anoplarchus spp./Cebidichthys	31.2	9.3
Xiphister mucosus	26.1	16.3
Oligocottus snyderi	7.9	6.0
Gobiesox maeandricus	7.7	2.8
Xiphister atropurpureus	4.7	2.2
Xererpes fucorum	4.2	0.4
Cottidae (juv.)	0.3	0.8
Cebidichthys violaceus	0.2	3.5
Gibbonsia spp.	0.2	0.3
Clinocottus recalvus	0.2	--
Oligocottus spp.	0.1	0.1
Artedius lateralis	0.1	--
Porichthys notatus	0.1	--
Stichaeidae/Pholididae	--	2.0
Anoplarchus purpurescens	--	1.7
Xiphister spp. (juv.)	--	1.2
Gibbonsia metzi	--	< 0.1
Typhlogobius californiensis	--	< 0.1
Artedius spp.	--	< 0.1
Total:	83.1	46.7

Black Abalone

Species of Concern: Withering Syndrome Disease

- “No take” management measure in effect via Fish and Game
- Heat known to exacerbate disease
- Disease first seen in Diablo Cove in 1988, radiated outward from Cove to control stations
- Discharge of heat to formerly pristine abalone habitat

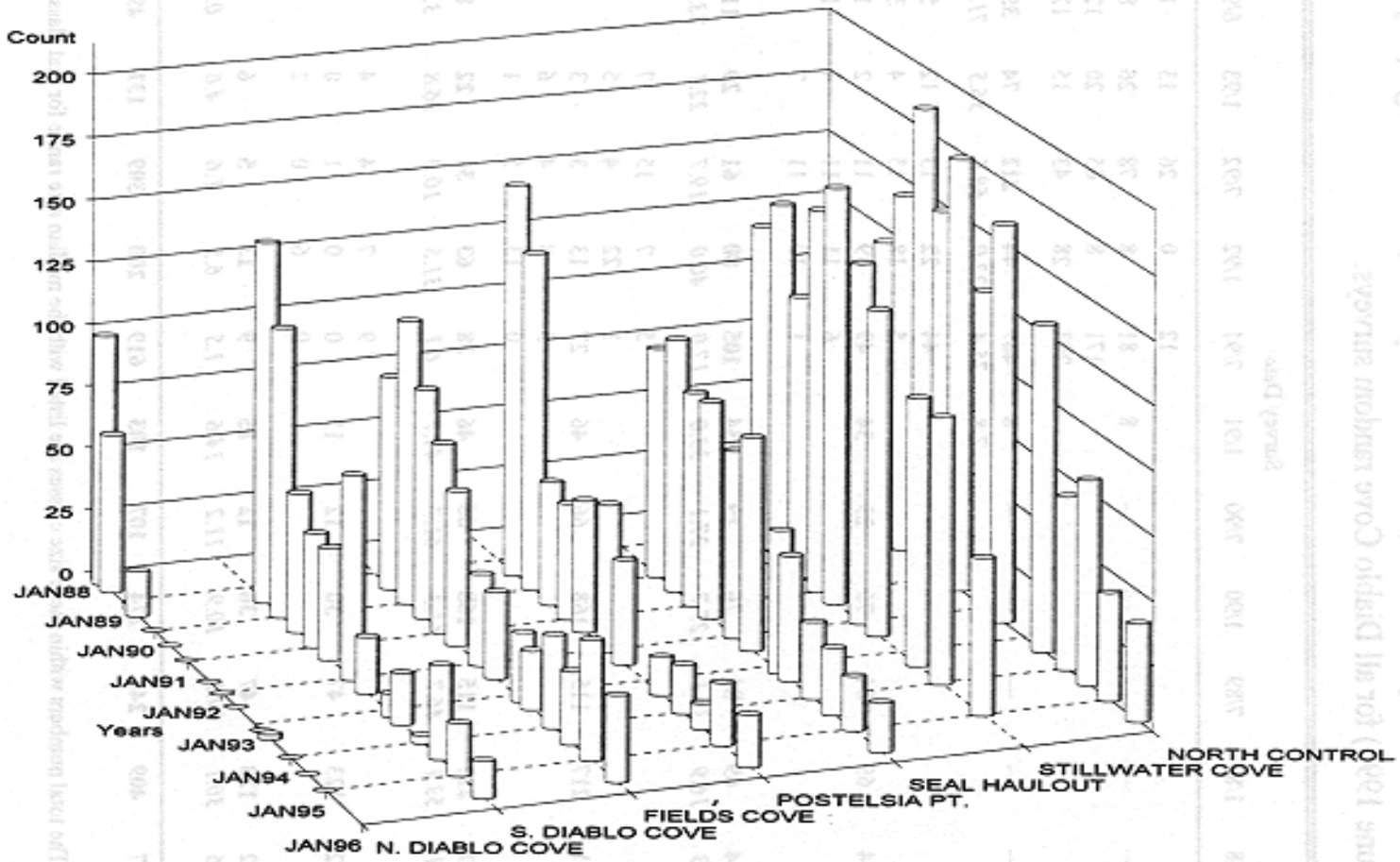
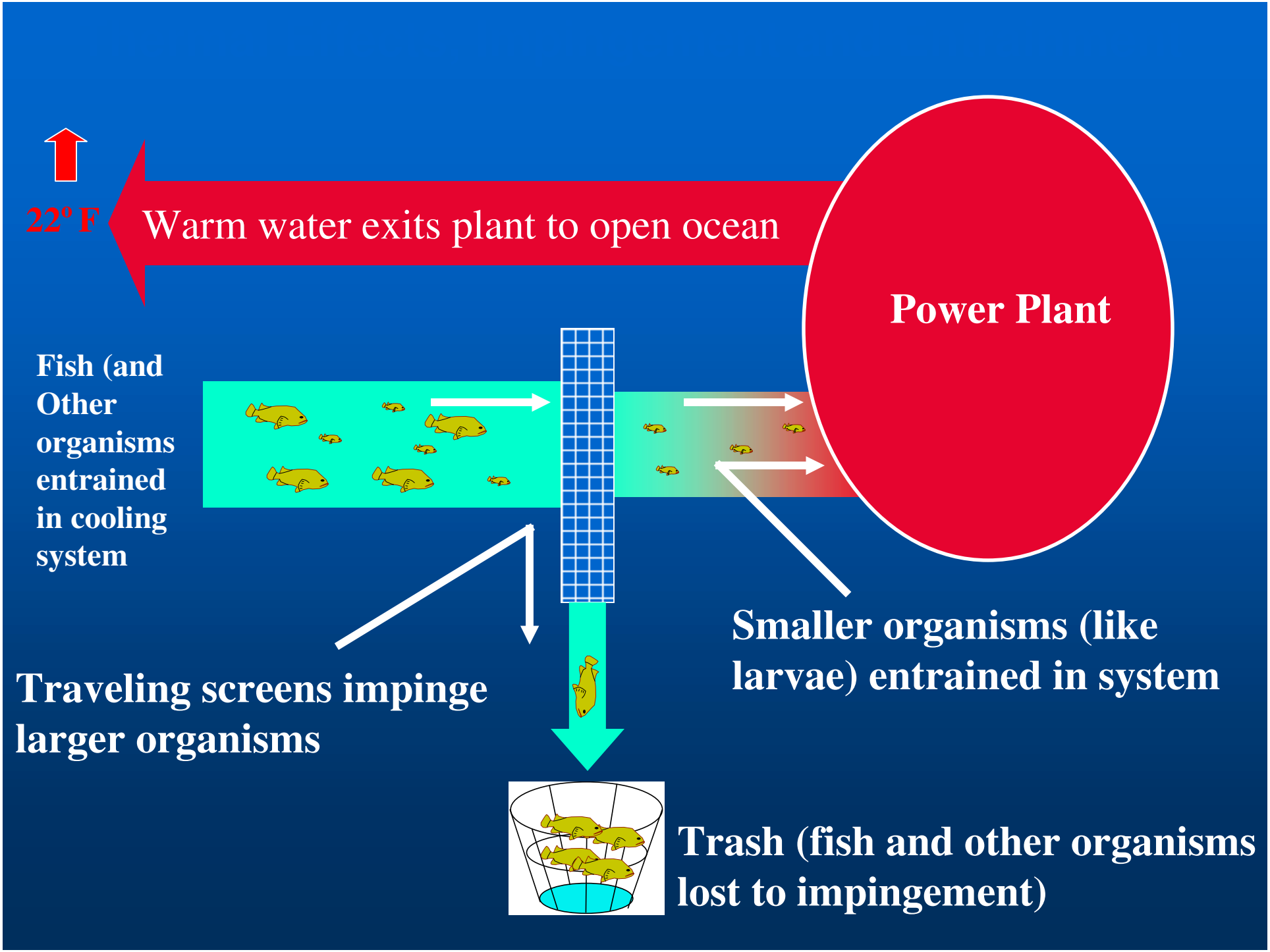


Figure 3-46. Black abalone, *Haliotis cracherodii*, total counts over time on the 10-meter stations. All surveys were completed after commencement of commercial power plant operation.

Entrainment/Impingement

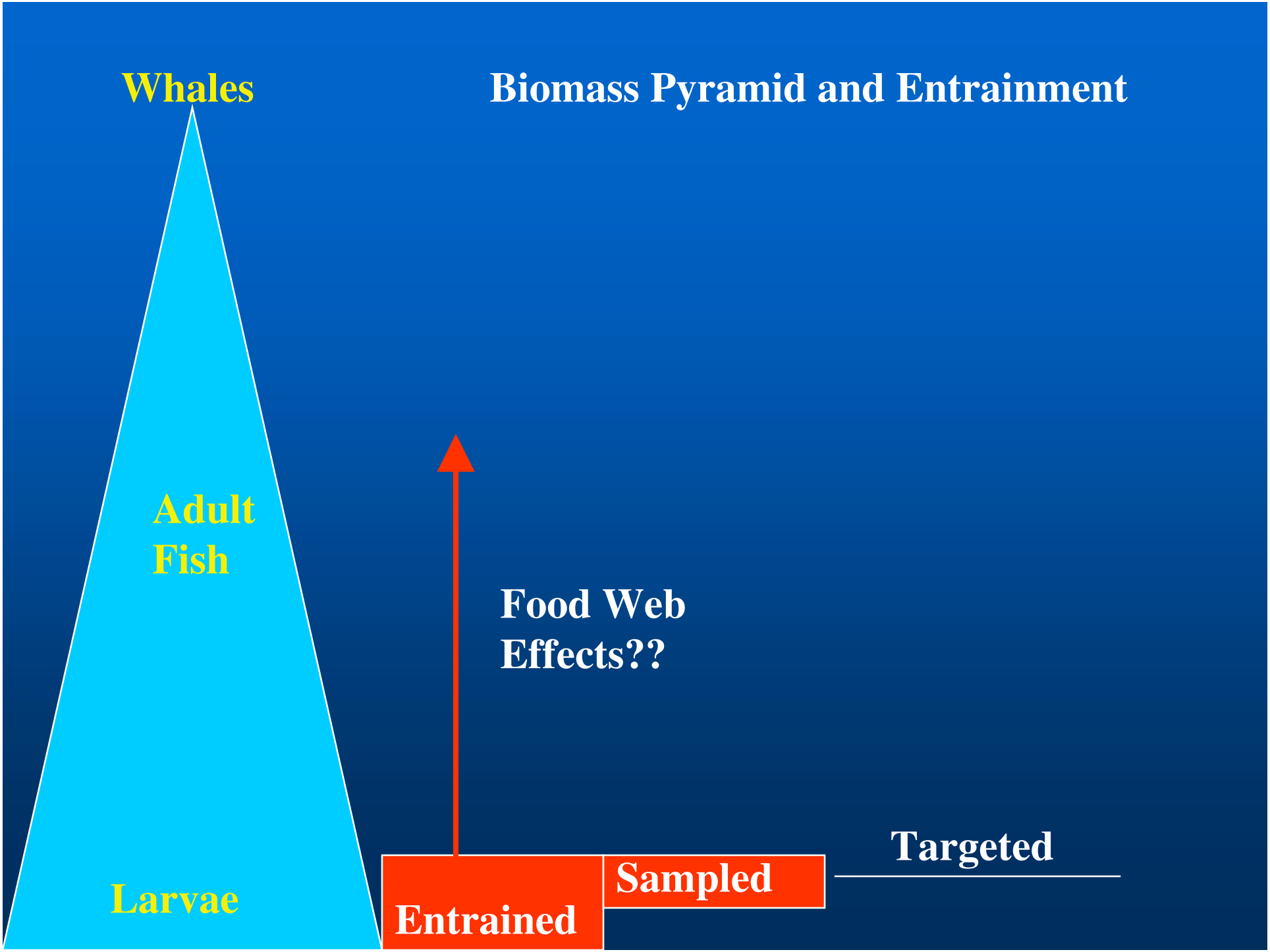

22° F
Warm water exits plant to open ocean
Power Plant
Fish (and Other organisms entrained in cooling system
Traveling screens impinge larger organisms
Smaller organisms (like larvae) entrained in system
Trash (fish and other organisms lost to impingement)

2.5 billion gallons per day

Football Field

300 ft x 150 ft

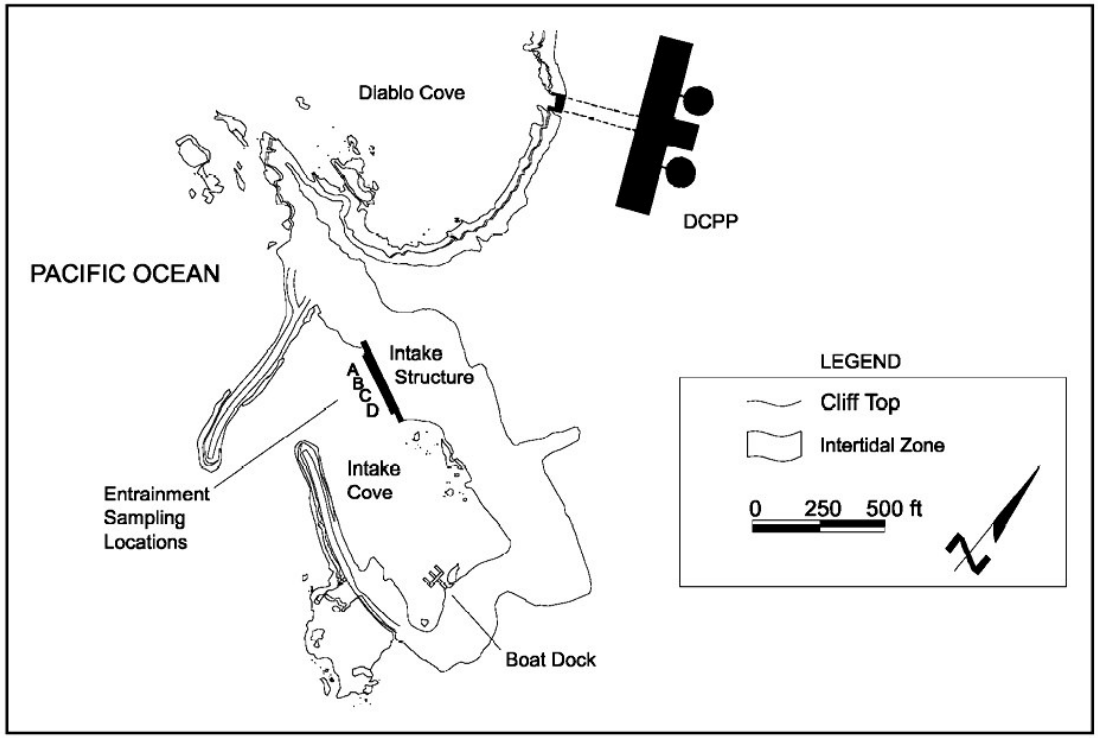
The tank would be 7, 300 feet high


Whales
Biomass Pyramid and Entrainment
Adult
Fish
Food Web
Effects??
Larvae
Entrained
Sampled
Targeted

Targeted Taxa

- Nearshore Taxa
  - Smoothhead sculpin
  - Monkey face prickleback
  - Clinid kelpfishes
- Subtidal and Pelagic Taxa
  - Painted greenling
  - Snubnose sculpin
  - Cabezon
  - Blackeye goby
  - Pacific sardine
  - Northern anchovy
  - White croaker
  - Blue rockfish
  - KGB rockfish
  - Sanddabs
  - California halibut
  - Brown rock crab
  - Slendercrab

Estimation of Entrainment



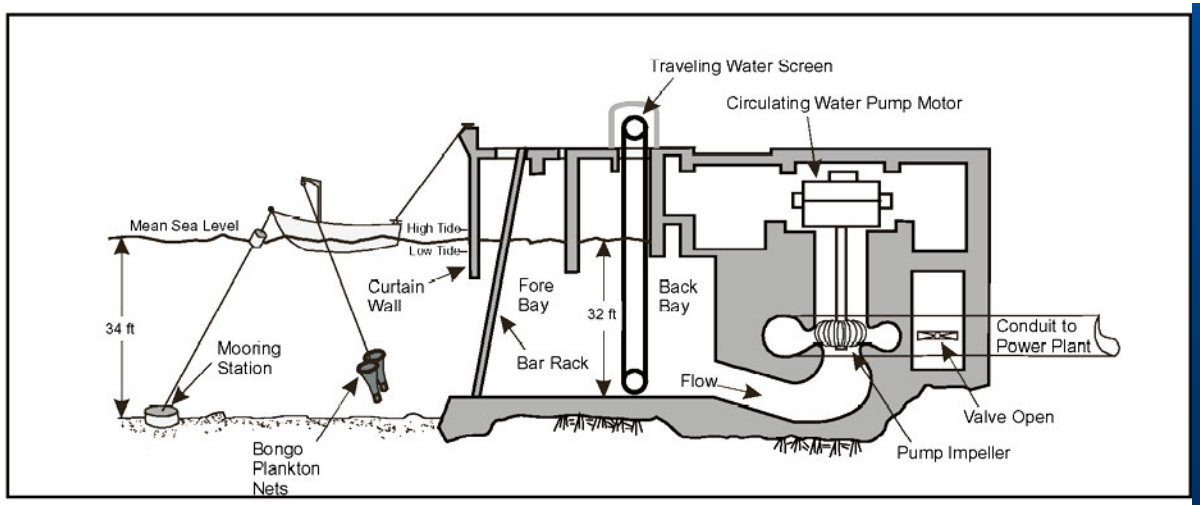


Figure 4-2. Cross-section view of the DCPP intake structure illustrating the location of the entrainment sampling sites.

Massive labor effort to identify and count taxa

Estimation of Population at Risk
Step 1: Study Grid

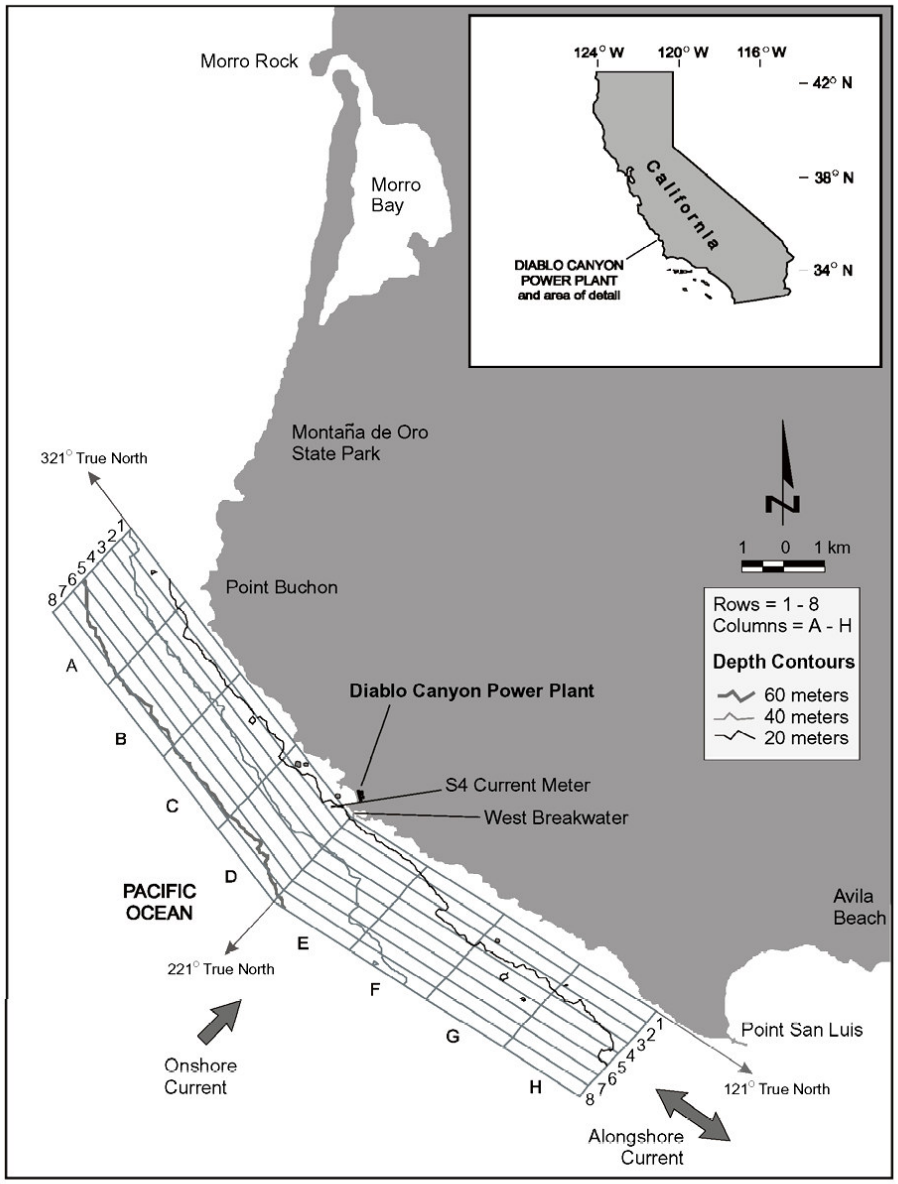


Figure 4-3. DCPP 316(b) study grid and depth contours.

H	G	F	E	D	C	B	A
8	8	8	8	8	8	8	8
7	7	7	7	7	7	7	7
6	6	6	6	6	6	6	6
5	5	5	5	5	5	5	5
4	4	4	4	4	4	4	4
3	3	3	3	3	3	3	3
2	2	2	2	2	2	2	2
1	1	1	1	1	1	1	1

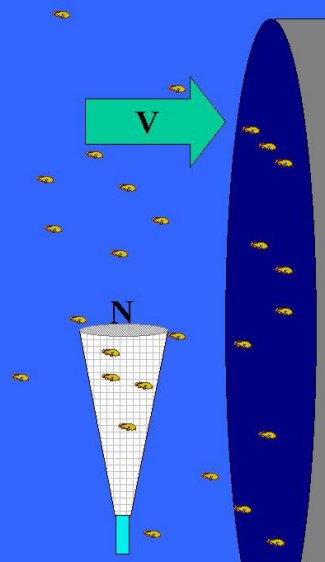
DCPP Intake Cove

Figure 4-4. An example of the "ping-pong" sampling track employed in grid cell sampling; the starting cell (F1) and the initial southward direction of the transect were randomly selected. All 64 cells are sampled during the 72-hour survey period, weather permitting. DCPP' s Intake Cove is located east of the juncture between cells E1 and D1.

Impingement Impacts

- Impingement
  - Few hundred fish per year (insignificant)

Estimation of larval losses due to entrainment



1. Calculate volume of cooling water entering the plant per year (V)
2. Measure concentration of larvae (number per volume) that are entrained (N)
3. *Assume no survival of larvae through the plant* – then
4. NV = the annual loss of larvae due to entrainment

The estimates of larvae entrained and the population at risk allow calculation of the Proportional Mortality (Pm) for a given species - **This represents the fraction of the population at risk that is lost to entrainment**

Estimation of Source Water Population

Estimation of Population at Risk

Step 2: Extrapolation to Source Water Body

Two Estimates of Larval Duration (from sizes)

1. Mean Duration (days)
2. Maximum Duration (days)

Estimate of Transport by Currents (distance /day)

Larval duration X Transport =

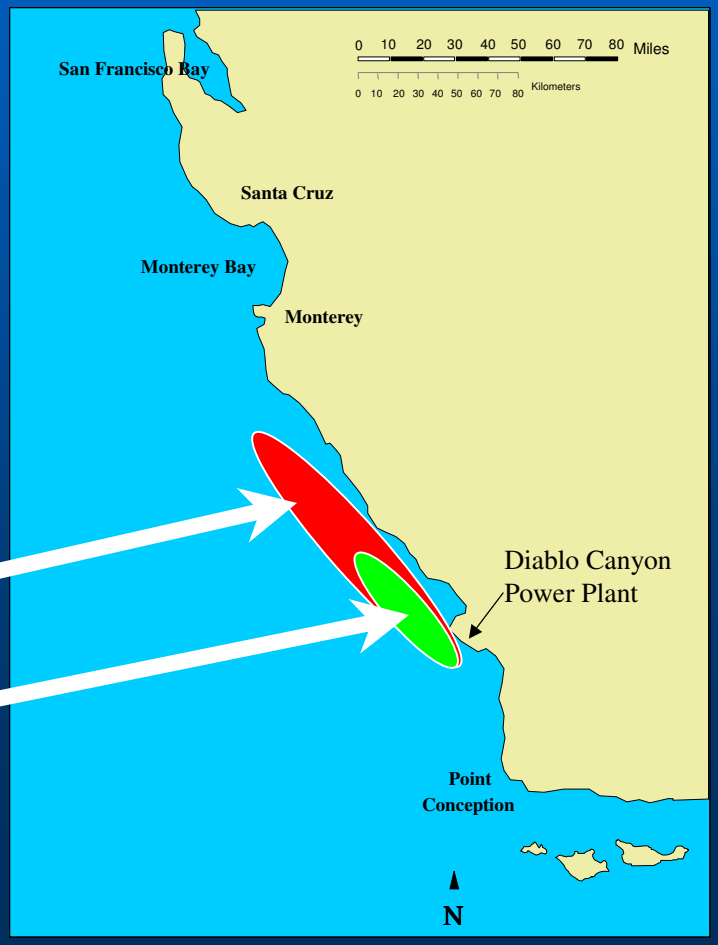
Source Water Body Length

Based on:

1) Maximum larval duration,

or

2) Mean larval duration



Entrainment

- Large source water bodies
  - Up to ~ 100 km of coastline
- Relatively large proportional larval mortality
  - Average proportional mortality is about 10% for rocky reef fish species, from an average source water body of 73 km
  - HPF analysis: 300 to 600 acres of reef habitat will replace most losses

Operational Changes

- Variable speed pumps
  - Not applicable for base load facility
- Seasonal power reduction
  - Not applicable for base load facility
  - Costs in hundreds of millions range
  - Larval spawning year round
    - No endangered species

Intake Technologies

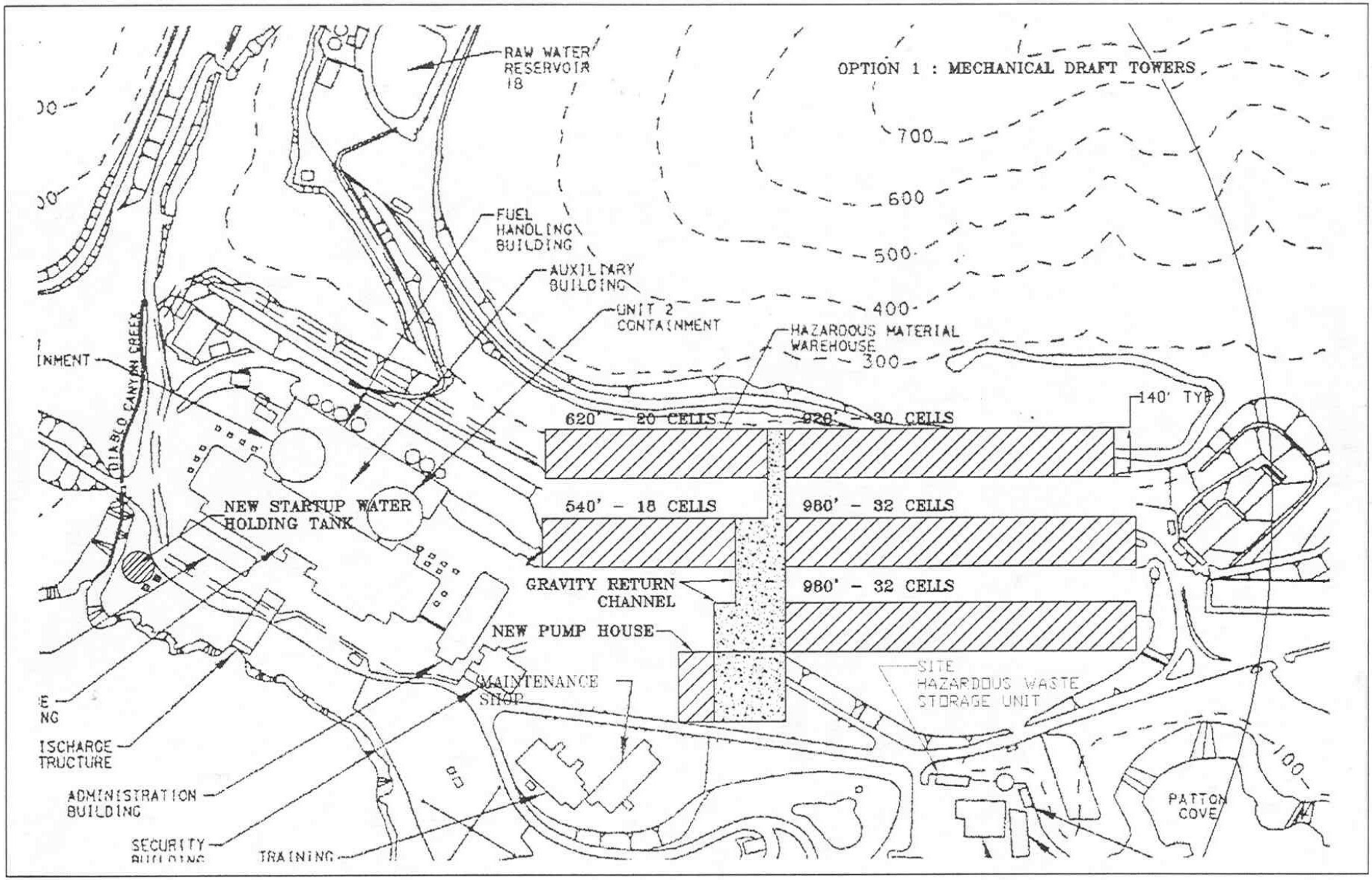
- Gunderboom
  - Not feasible
- Offshore Intake structure
  - Effectiveness is site-specific
    - Major construction impacts
    - Feasibility: No reference to similar case
    - $300 to $455 million @ 1100 feet offshore
    - Further offshore distance needed
    - Change in entrainment depends on distance offshore

Intake Technologies

- Fine Mesh Screens
  - Effectiveness relative to OTC not established
    - Causes larval mortality
    - Issue is benefit over once-through cooling
  - Little data available
  - No similar sites
  - Major reconstruction of intake structure
    - Double size of structure
  - Cost approximately $650 million
    - Depends largely on downtime

Cooling Alternatives
Independent Review

- **Saltwater Towers**
  - Technology can significantly reduce entrainment
  - 132 towers @ 60ft x 60ft x 65 ft high
  - Available space issue at DCPP
  - Existing facilities and utilities must be moved
  - Parking lot, service road, large warehouse, and offices
  - Rezoning of adjacent land required
  - Cost $1.3 billion+
  - County APCD will not permit them
  - Salt drift impacts


OPTION 1 : MECHANICAL DRAFT TOWERS
RAW WATER RESERVOIR 18
FUEL HANDLING BUILDING
AUXILIARY BUILDING
UNIT 2 CONTAINMENT
HAZARDOUS MATERIAL WAREHOUSE
DIABLO CANYON CREEK
700
600
500
400
300
100
140' TYP
620' - 20 CELLS
920' - 30 CELLS
540' - 18 CELLS
980' - 32 CELLS
980' - 32 CELLS
NEW STARTUP WATER HOLDING TANK
GRAVITY RETURN CHANNEL
NEW PUMP HOUSE
MAINTENANCE SHOP
SITE HAZARDOUS WASTE STORAGE UNIT
ADMINISTRATION BUILDING
SECURITY
TRAINING
PATTON COVE

Closed Cooling

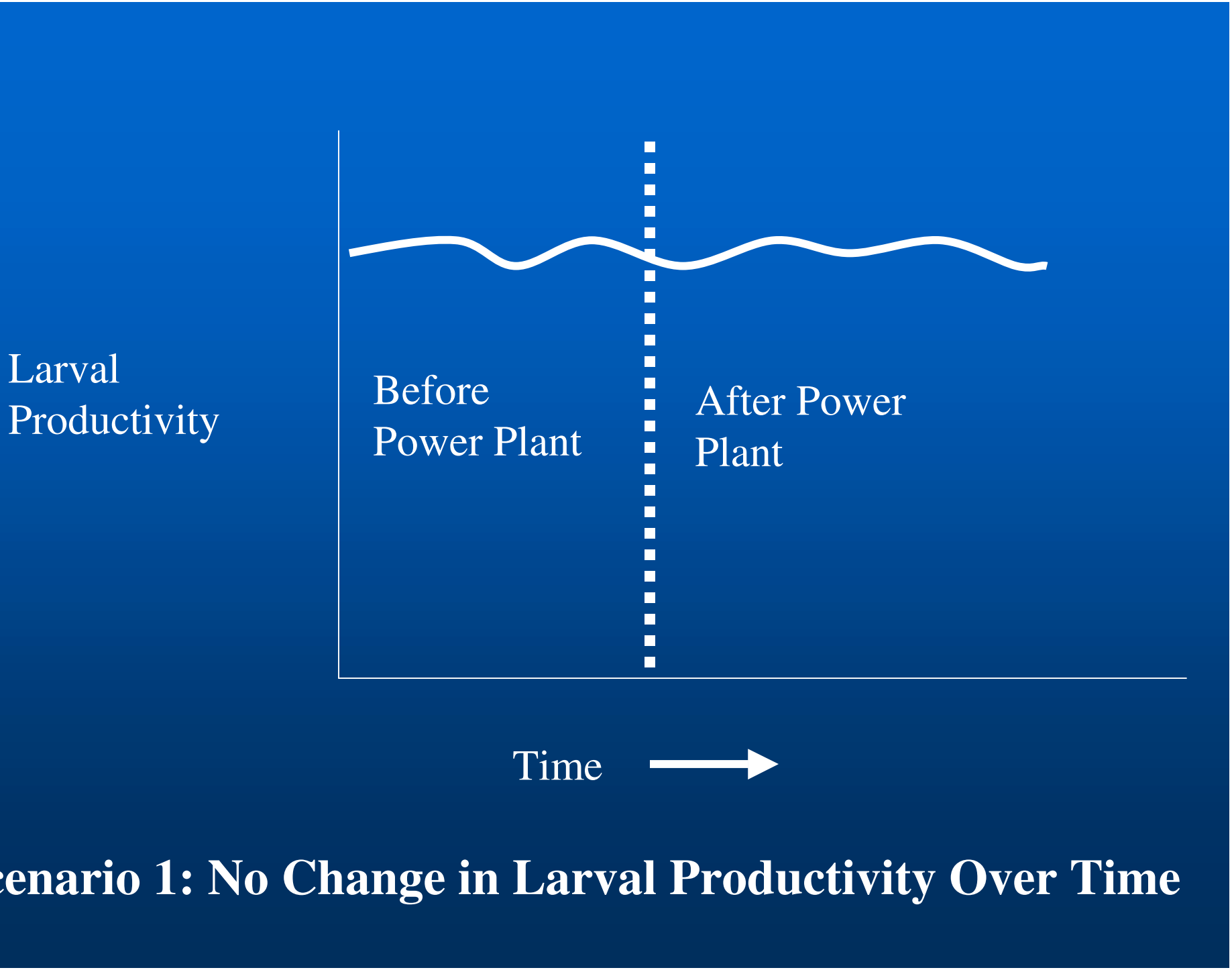
- Freshwater towers
  - Billions
  - 50 MGD freshwater desal plant needed
  - Not feasible (space)

Closed Cooling

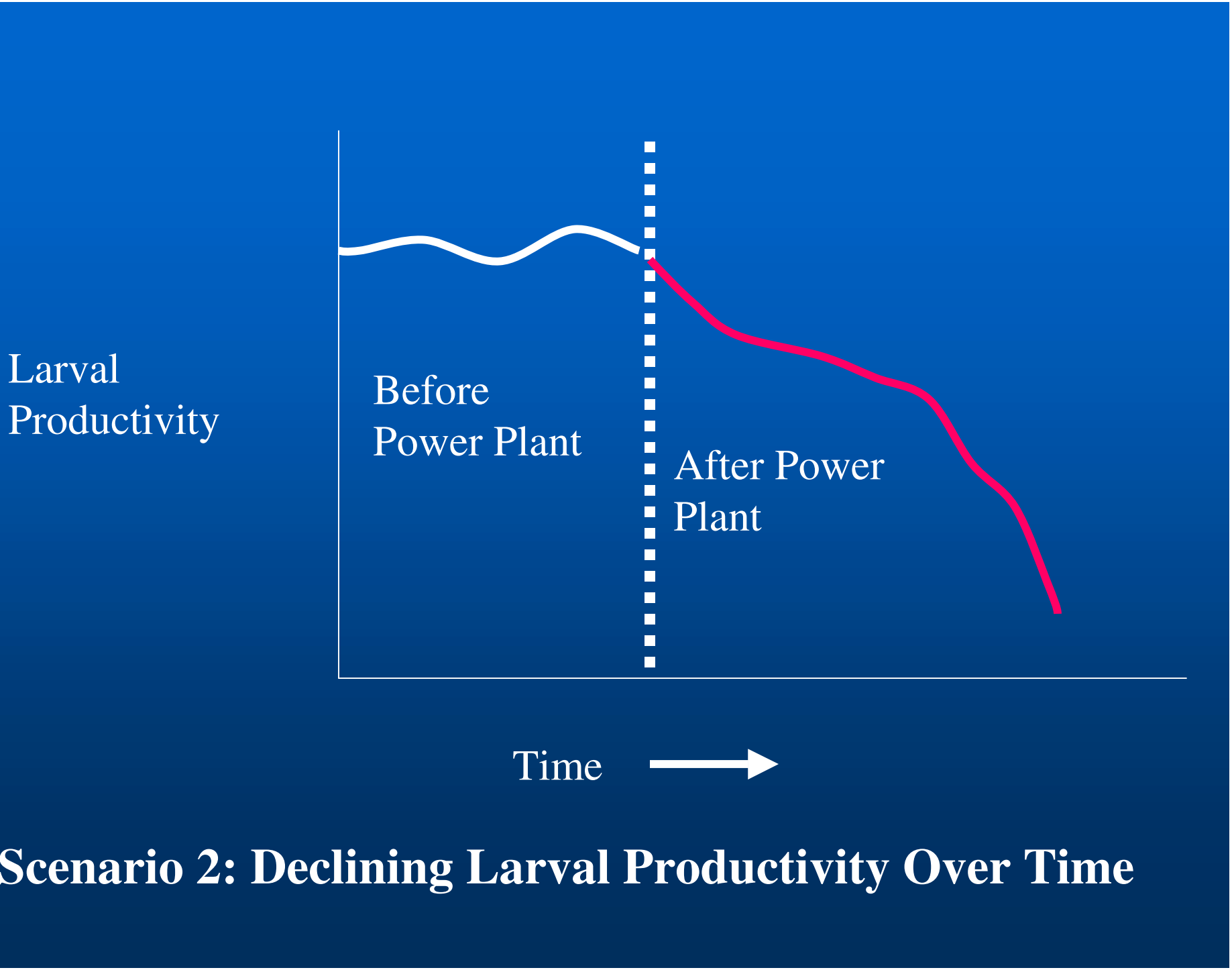
- Dry Cooling
  - Several billion
  - No precedent
  - Not physically possible
  - Footprint = 5 football fields

Mitigation

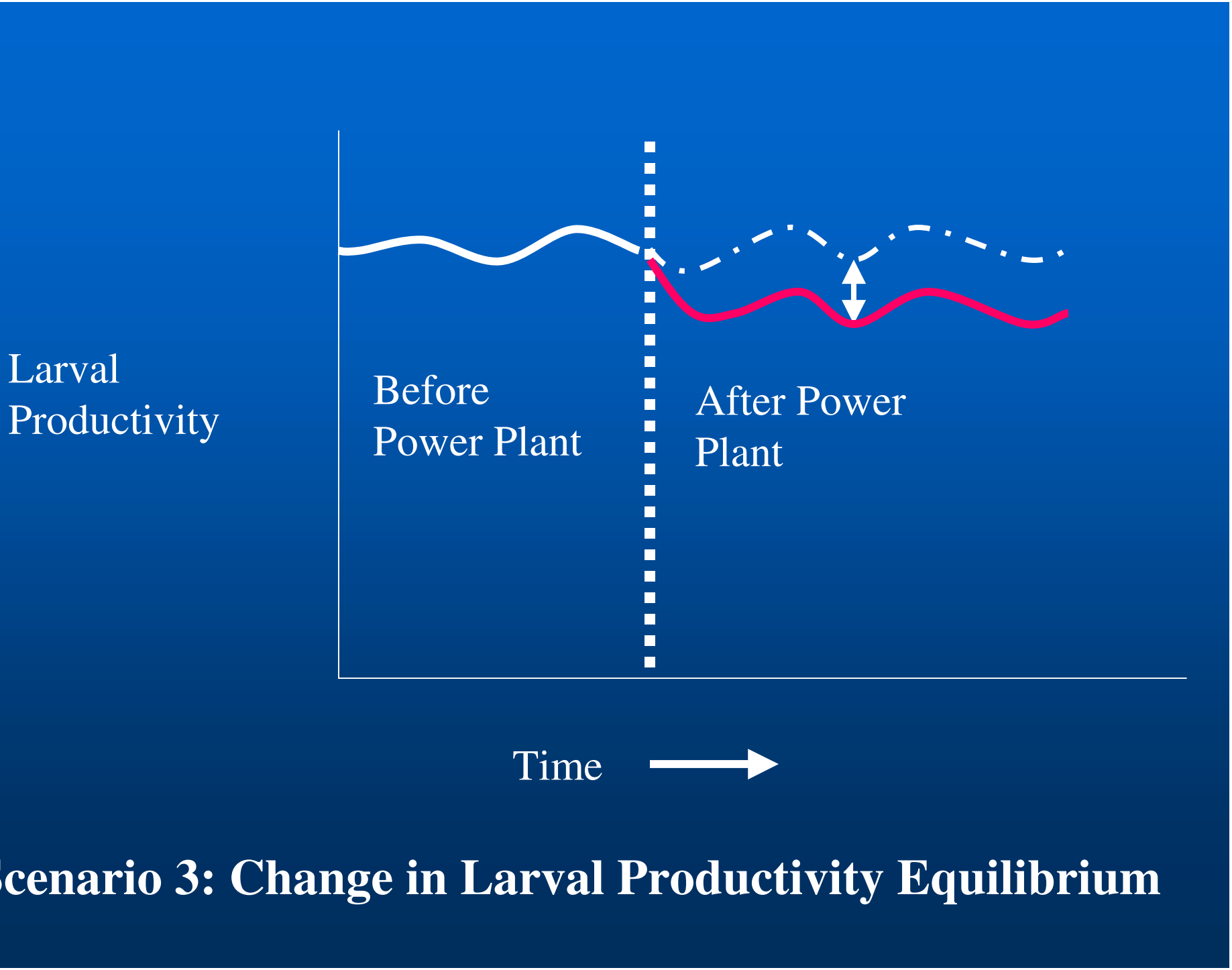
- Habitat Production Forgone
  - Artificial reefs
    - Direct mitigation
    - 300 to 600 acres will replace most losses
    - ~$10 to $26 million
  - Funding for marine reserves
    - Bigger fish = more larvae
    - Indirect mitigation



Scenario 1: No Change in Larval Productivity Over Time



Scenario 2: Declining Larval Productivity Over Time



Scenario 3: Change in Larval Productivity Equilibrium

Estimation of Proportional Mortality

= the proportion of population at risk that is lost to entrainment

Daily Loss Rate = Number Entrained / Number in Population at Risk = NE/NR

NR = Number in Study Grid X (Length of Source Water Body/Length of Study Grid)

Thus, the **Proportional Mortality** (PM) = The integration of **Daily Loss Rate** over the period at risk (mean or max larval duration)

PM is expressed as the proportion of larvae lost due to entrainment in a source water body of size X

1. **PM has two parts: loss rate and size of source water body (X)**
2. **The size of the source water body (X) will vary by species**

Major Assumptions of the Approach

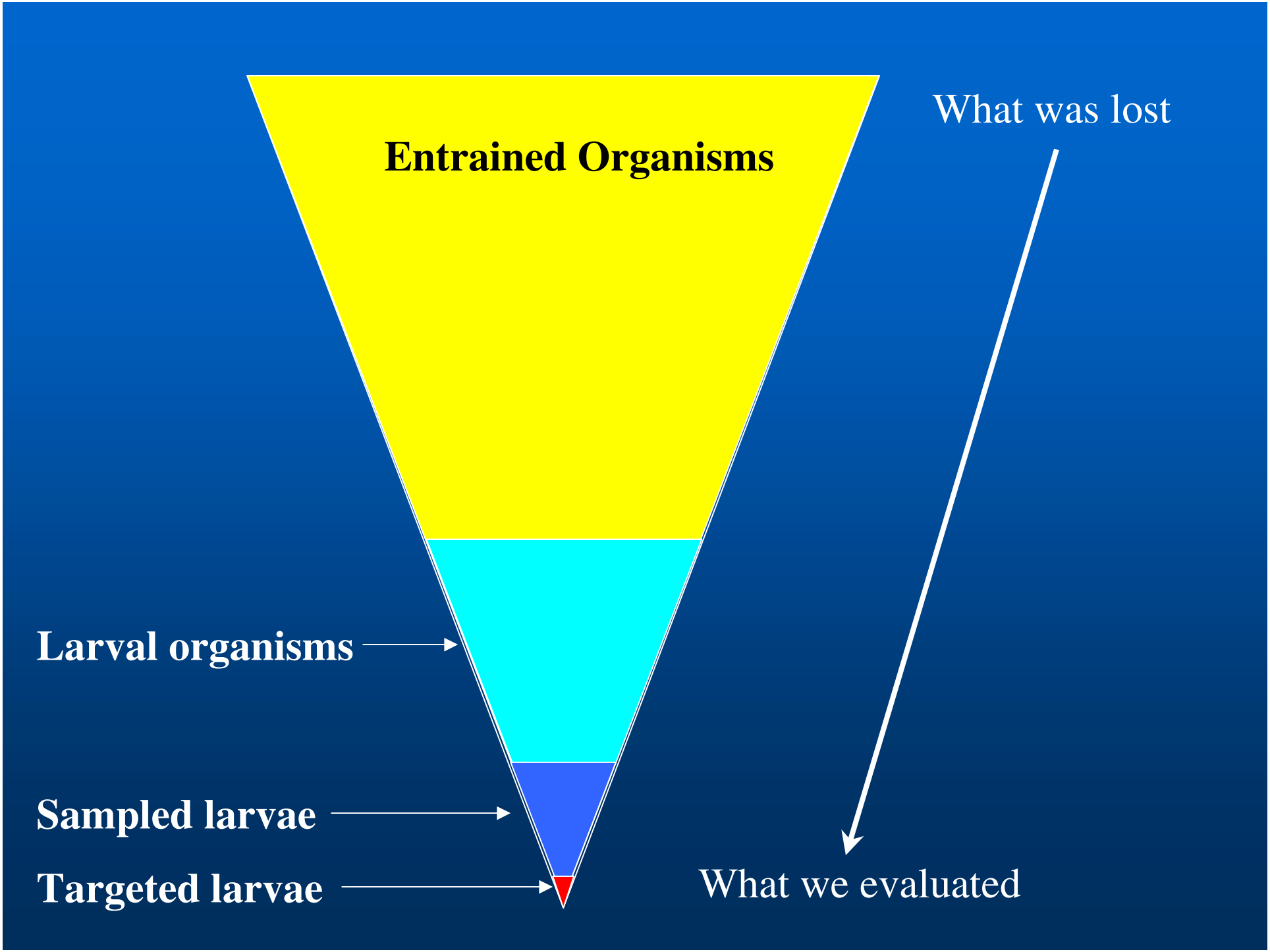
1. All organisms entrained are killed
2. Estimation of a subset of species would provide a realistic approximation of the level of impact
   - Only larval forms were used, no holoplankton
   - Mostly fish species were evaluated, crab larvae were also evaluated – no other invert or algal species
   - Species sampled represented a range of life histories that allow understanding of the likely impacts to other (unsampled) species
3. Entrainment sampling was sufficient and unbiased
4. Grid sampling was sufficient and unbiased
5. Extrapolation from the grid to the source water body was realistic
   - Use of larval size to approximate age was appropriate
   - Use of mean and max larval duration yielded realistic values for Pm and source water body estimates
   - Estimates of currents were sufficient and unbiased
   - Larval behavior did not affect estimates of source water bodies
6. Two years of sampling were sufficient to capture variability in Pm estimates

Possible solution

- Use Habitat Production Foregone (HPF) as currency
  - This value represents the area or distance that would have to be added to the source water body to compensate for the effects of entrainment
- Now calculate the average HPF values as best estimate of ecological impact

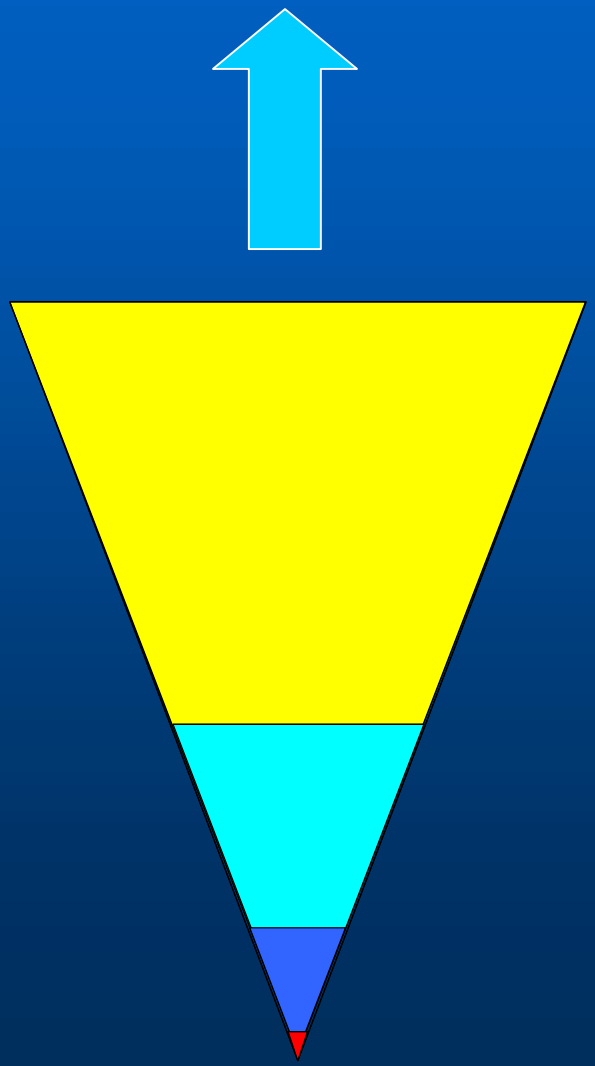
Major Limitation of Approach

- Only direct effects on a subset of taxa could be evaluated
  - No indirect effects evaluated
  - No higher order effects evaluated (effects on ecosystem function)


Entrained Organisms
What was lost
Larval organisms
Sampled larvae
Targeted larvae
What we evaluated

Ecosystem effects – all the things that use planktonic organisms

Completely Unstudied



Morro Bay Power Plant

Morro Bay Power Plant

- Began operation in 1950's (preceding most environmental laws & regulations)
- 1002 MW (design)
- 707 MGD (design flow, average is lower)

Modernized Plant

- 1200 MW (design)
- 475 MGD (design flow)

Estimation of thermal plume

- Prediction of Plume under future condition

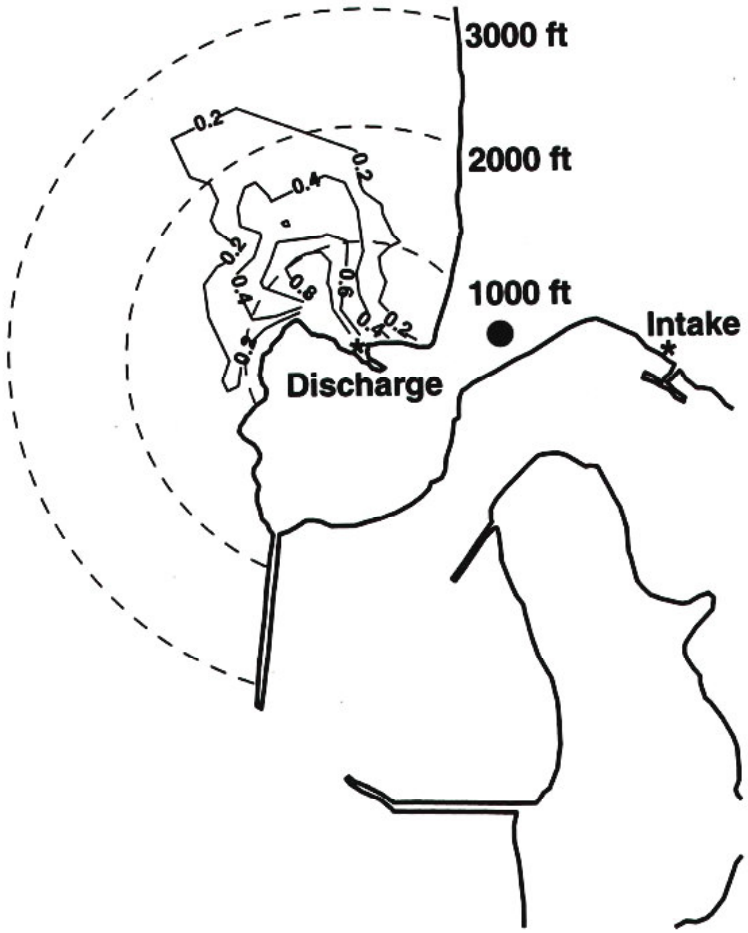
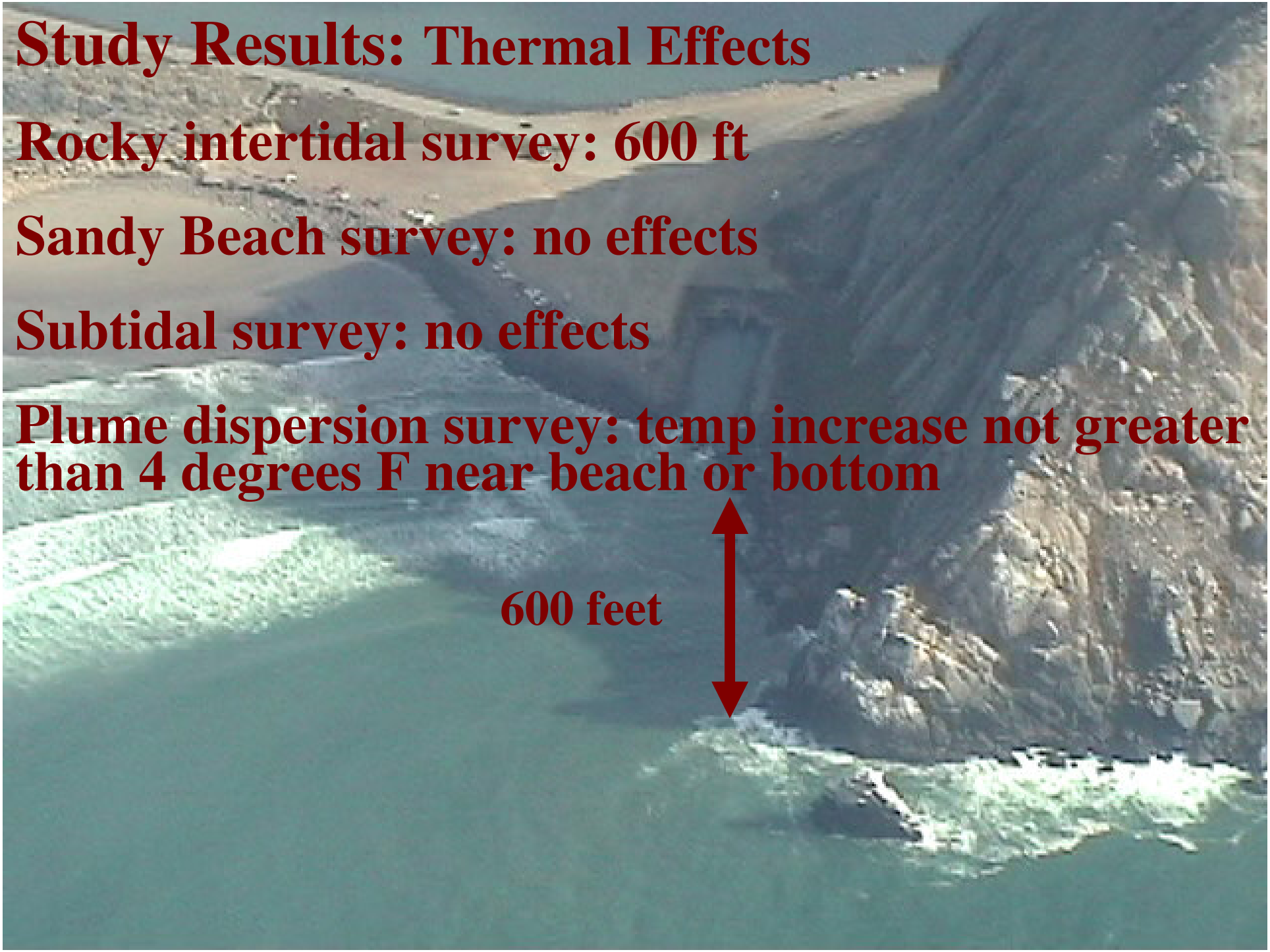


Figure 2-45. Probability of surface temperature anomaly exceeding 4°F (2.2 °C) under projected future maximum load conditions estimated by reducing the observed pattern of Figure 2-39 to be 55% of its original size according to the reductions in weighted maximum heat load in Table 2-1.


Study Results: Thermal Effects
Rocky intertidal survey: 600 ft
Sandy Beach survey: no effects
Subtidal survey: no effects
Plume dispersion survey: temp increase not greater than 4 degrees F near beach or bottom
600 feet

Study Results

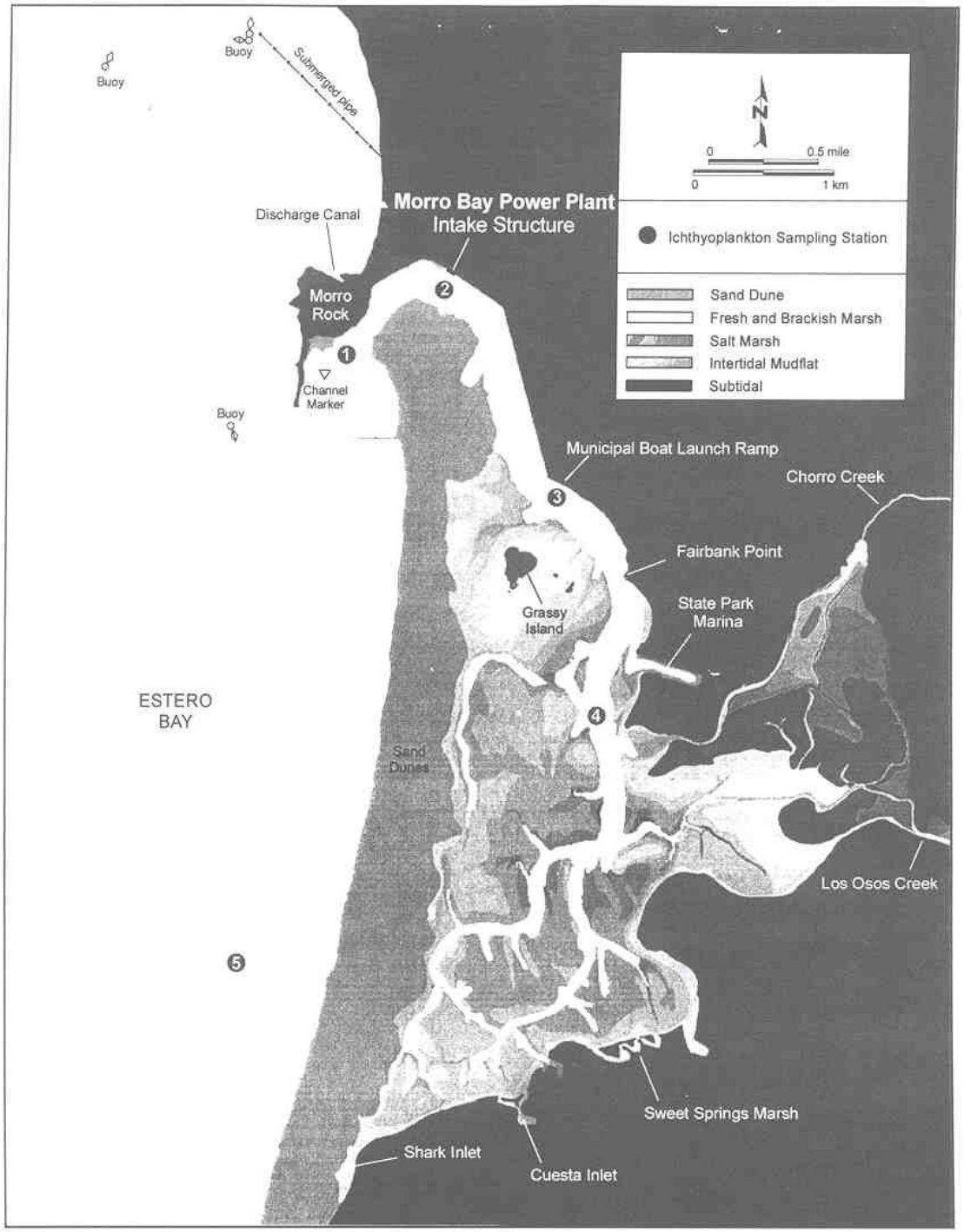
Impingement:

1.4 tons fish/yr
0.4 tons inverts/yr

Entrainment:

17 to 33% larval loss of estuarine larvae

3% for coastal taxa



Summary...

- **Impingement impacts minor**
  - **Unknown if new regs will require action**
- **Thermal discharge impacts not unreasonable per Thermal Plan**
  - **Reasonable protection of beneficial uses**
    - **Move discharge offshore: $20 million**
- **Entrainment impacts are significant**
    - **relatively large proportional larval loss from estuary**

Operational Changes

- Shut down pumps when possible
  - Fixed speed
- No seasonal slow down
  - Larval production is year round
  - No endangered species
- Clean traveling screens regularly
  - Less debris = less fish trapped

Intake Technologies

- Offshore intake structure
  - $30 million
  - Construction impacts
  - Transfers problem (impingement goes up)
- Fine mesh screens
  - $8 million
    - does not include down time
    - does not account for new regs: 0.5 fps through screen v
  - Experimental in marine environment
  - Kill fewer larvae than once-through cooling?

Intake Technologies

- Gunderboom
  - $8 million
  - Experimental (we don't like it)
  - Will not fit in Morro Bay
- Variable speed pumps
  - Flow reduction unknown (depends on operation)

Closed Cooling Technologies

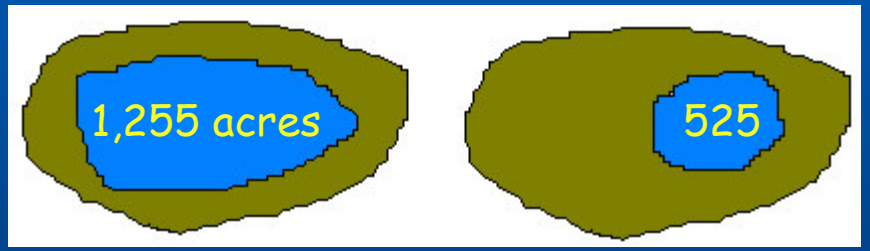
- Freshwater towers
  - ~$40 million
  - Need ~8 mgd, not available
  - Noise, visual, land use issues
- Saltwater towers
  - ~$40 million
  - County APCD will not permit them
  - Noise, visual, land use issues
- Dry cooling
  - ~$100 million (Duke say $250 million)
  - City says no
  - Noise, visual, land use issues
  - Energy Commission PMPD says no

Mitigation

- Habitat Production Forgone
  - 17 to 33% loss
  - 2300 acres X 0.17 = 391 acres
  - 2300 acres X 0.33 = 759 acres
  - Convert to restoration costs
    - $11 to 22 million
  - Cost to reduce sedimentation
    - $12 to $25 million
  - Duke agreed to $12.5 million

Is Habitat Enhancement Applicable?

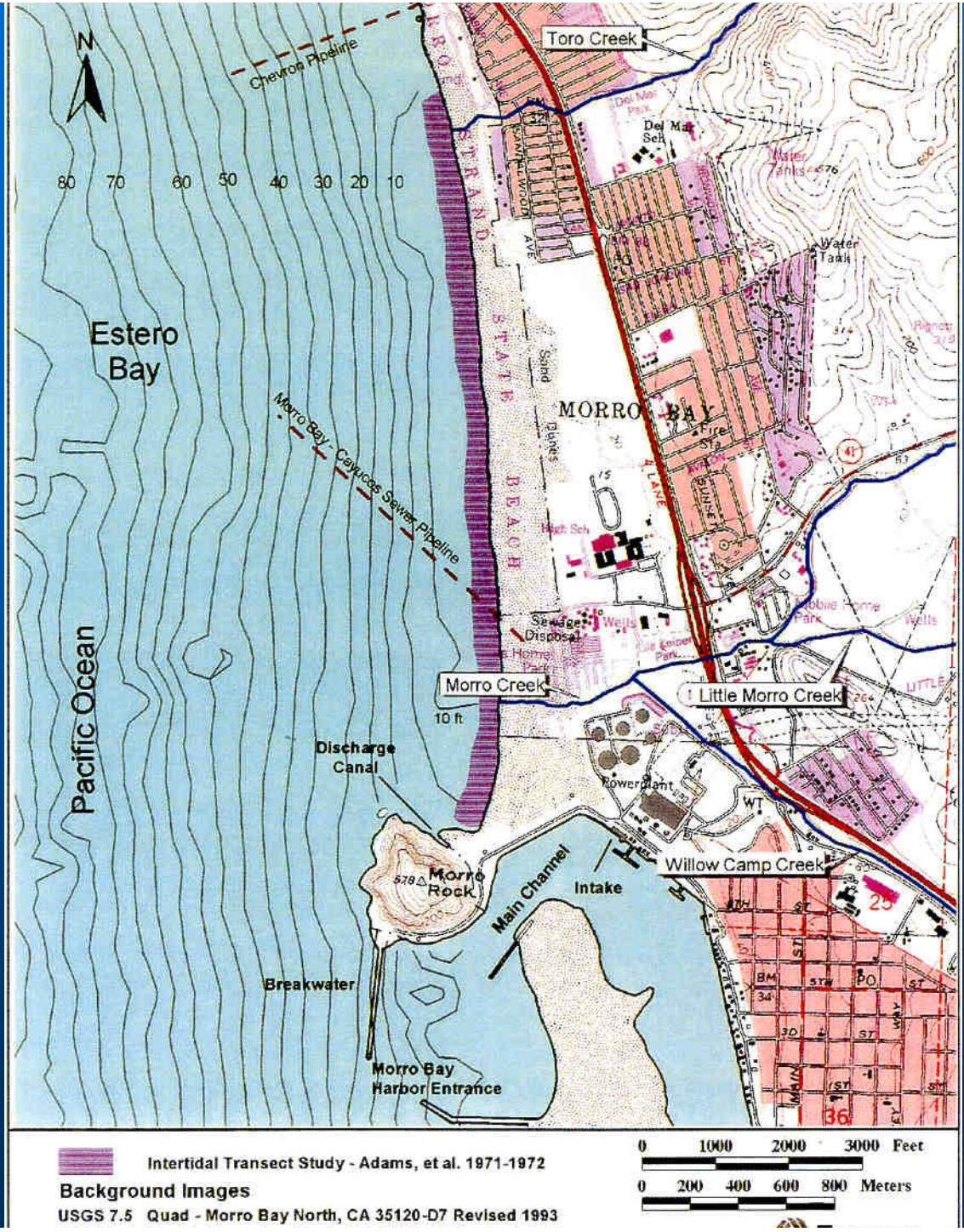
Water area reduction



1890's 1990's

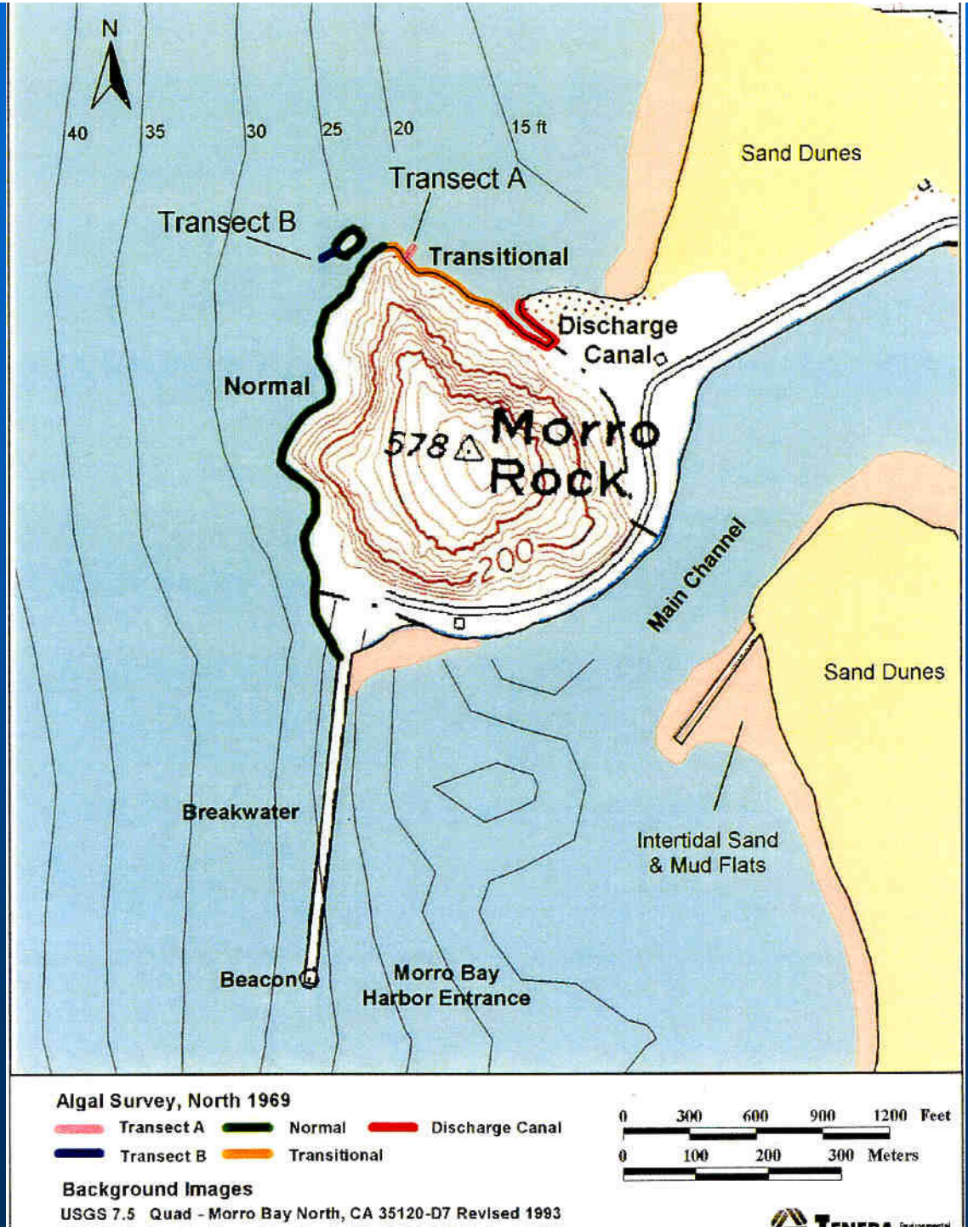
Morro Bay Power Plant
Historical Operation Versus Upgrade

- **Temperature**
  - Existing Permitted facility: 30 degrees delta T
  - New Facility: 20 degrees delta T
- **Cooling water volume**
  - Permitted: 707 MGD Design (actual is 688 MGD)
  - New Facility: 475 MGD Design


N
Chevron Pipeline
80 70 60 50 40 30 20 10
Estero Bay
Pacific Ocean
Morro Bay - Cayucos Sewer Pipeline
MORRO STRAND STATE BEACH
Toro Creek
Del Mar Park
Water Tanks
Water Tank
MORRO BAY
Fire Sta
Sand Blades
Sewage Disposal
Wells
Morro Creek
10 ft
Little Morro Creek
Discharge Canal
Powerplant
WT
Willow Camp Creek
Morro Rock
Main Channel
Intake
Breakwater
Morro Bay Harbor Entrance
Intertidal Transect Study - Adams, et al. 1971-1972
Background Images
USGS 7.5 Quad - Morro Bay North, CA 35120-D7 Revised 1993
0 1000 2000 3000 Feet
0 200 400 600 800 Meters

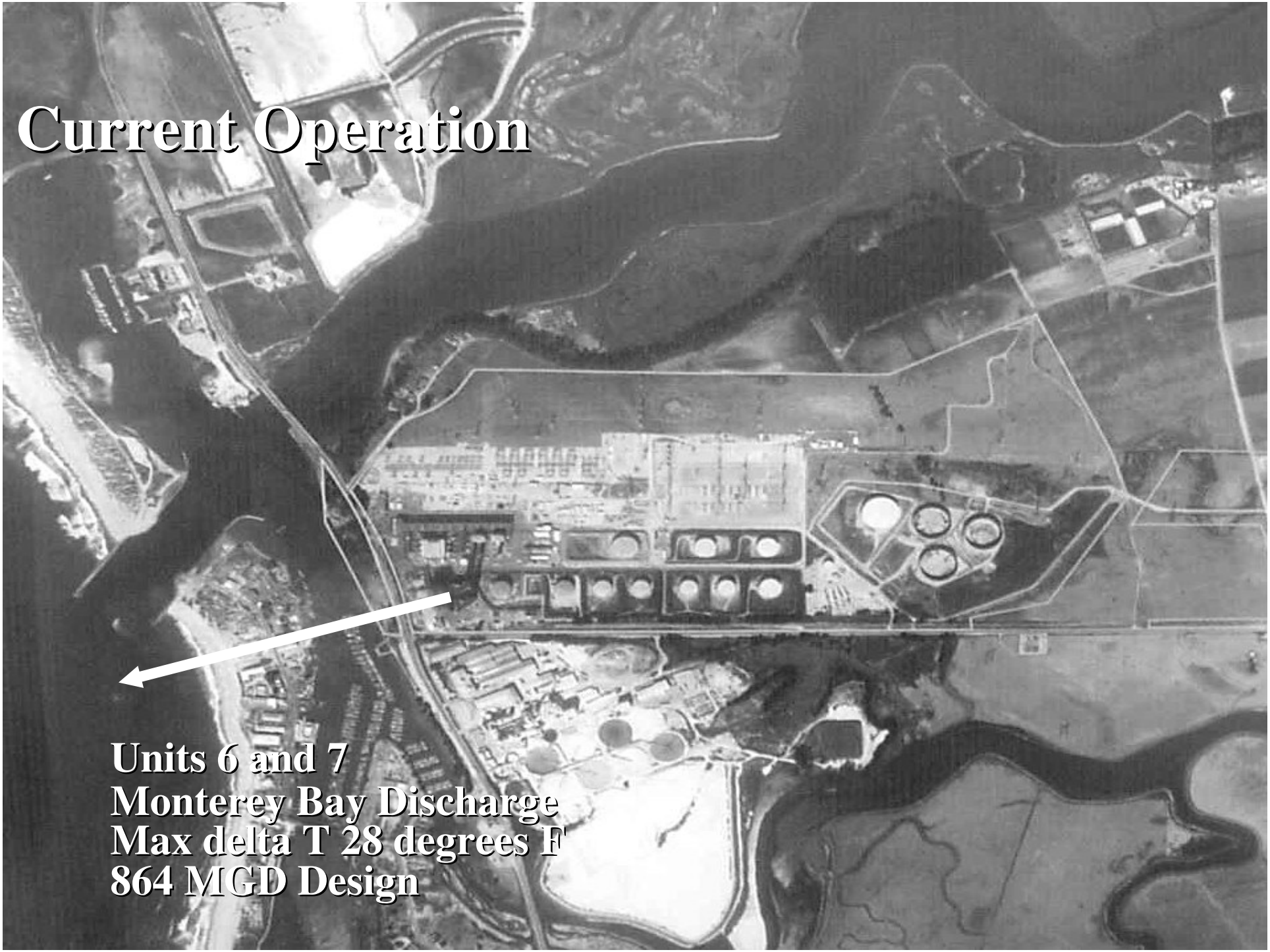

WELCOME TO MORRO BAY


DANGER
DANGER


N
40
35
30
25
20
15 ft
Transect A
Transect B
Transitional
Sand Dunes
Discharge Canal
Normal
578
Morro Rock
200
Main Channel
Sand Dunes
Breakwater
Intertidal Sand & Mud Flats
Beacon
Morro Bay Harbor Entrance
Algal Survey, North 1969
Transect A
Normal
Discharge Canal
Transect B
Transitional
0 300 600 900 1200 Feet
0 100 200 300 Meters
Background Images
USGS 7.5 Quad - Morro Bay North, CA 35120-D7 Revised 1993


Historic Operation
Pre 1995
Units 1-5
Elkhorn Slough Discharge
Max delta T 18-26 degrees F
550 MGD design
Units 6 and 7
Monterey Bay Discharge
Max delta T 28 degrees F
864 MGD Design

Current Operation



Units 6 and 7
Monterey Bay Discharge
Max delta T 28 degrees F
864 MGD Design


Future Operation
OLD Units 1-5
Elkhorn Slough Discharge
Max delta T 18-26 degrees F
550 MGD Design
NEW Units 1 and 2
Monterey Bay Discharge
Max Delta T 20 degrees
360 MGD Design
Units 6 and 7
Monterey Bay Discharge
Max delta T 28 degrees F
864 MGD Design

Entrainment at DCPP

- Overview of Study Design
- Estimates of Entrainment Losses
- Local Trends in Species Abundances
- What is the Solution?
  - Power Plant Modification
  - Marine Reserves

Entrainment at DCPP

- Overview of Study Design
- Comment on Technical Merit of Study
- Estimates of Entrainment Losses
- Comment on Utility of Examination of Local Trends in Species Abundances
- What is the Solution?
  - Power Plant Modification
  - Marine Reserves

Cooling System Alternatives
Context

- Legal Context
  - Effective?
  - Feasible?
  - Cost?

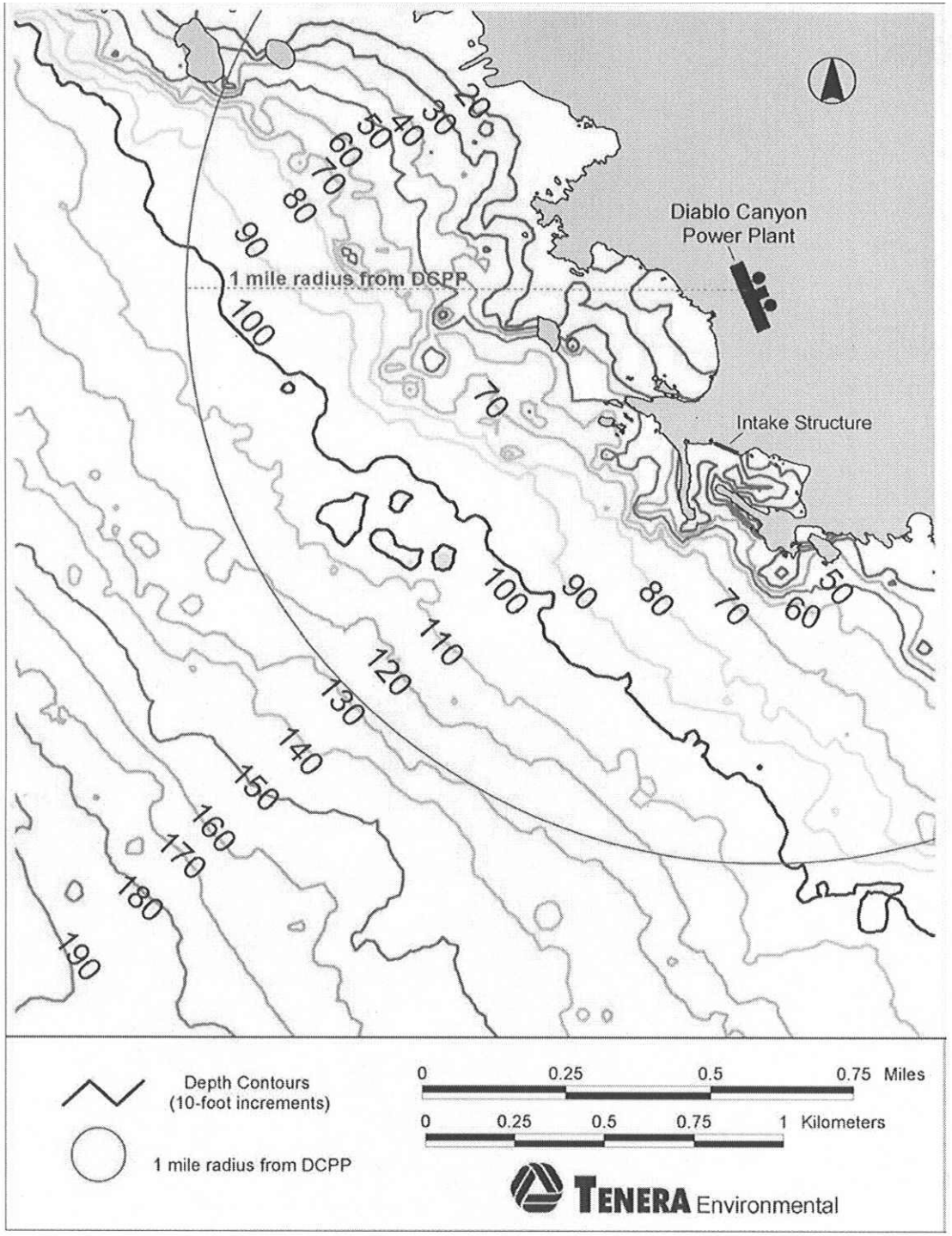
Entrainment Valuation

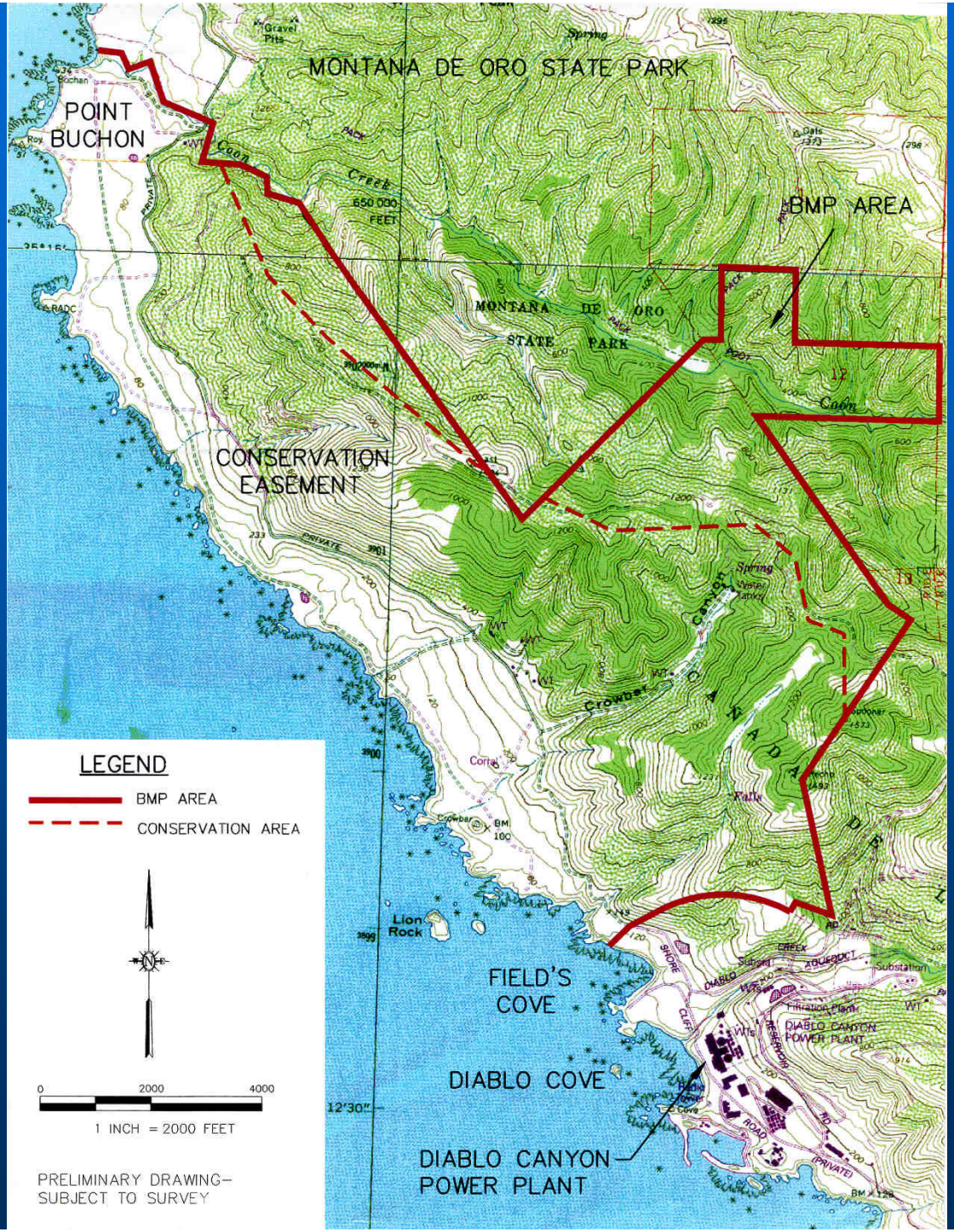
- Valuation report submitted by PG&E
  - Reviewed by Board's independent consultants
    - Stratus and Dr. Raimondi
- No mandatory valuation methods
  - Valuation not required by law
  - Regional Board has wide latitude in this area
- PG&E's valuation
  - NPV of losses: $15,786 to $1,905,757
  - Could be order of magnitude higher
  - Cost of alternatives is wholly disproportionate

Cooling System Alternatives Conclusion

- Saltwater towers and fine mesh screens are the only conceptually feasible alternatives
  - Effectiveness of fine mesh screens unknown
    - Weight of evidence does not support this alternative
  - Feasibility of saltwater towers unknown
    - Many site specific-obstacles
- Costs of alternatives are wholly disproportionate to benefit
- Under law, current system is BTA
  - Currently no requirement for mitigation

Bathymetry


Diablo Canyon
Power Plant
1 mile radius from DCPP
Intake Structure
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
Depth Contours
(10-foot increments)
1 mile radius from DCPP
0 0.25 0.5 0.75 Miles
0 0.25 0.5 0.75 1 Kilometers
TENERA Environmental


MONTANA DE ORO STATE PARK
POINT BUCHON
BMP AREA
CONSERVATION EASEMENT
MONTANA DE ORO STATE PARK
FIELD'S COVE
DIABLO COVE
DIABLO CANYON POWER PLANT
LEGEND
BMP AREA
CONSERVATION AREA
0
2000
4000
1 INCH = 2000 FEET
PRELIMINARY DRAWING–
SUBJECT TO SURVEY

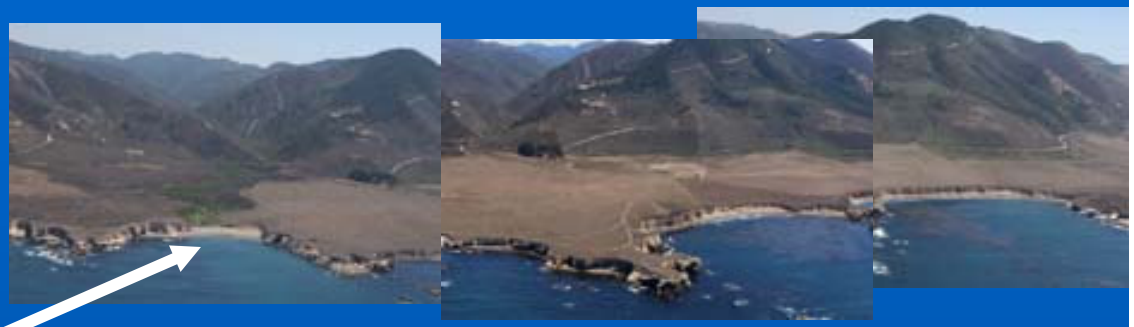
Conclusion…

- Existing cooling water system is BTA within current application of law
  - Effectiveness
  - Feasibility
  - Wholly disproportionate costs
- Thermal effects
  - Reasonable protection of beneficial uses
  - Alternatives not reasonable
    - Other impacts
    - Feasibility
    - Costs

Conservation Easement...

- **Conservation Values**
  - Preserve in nearly undeveloped state
  - Protect 5.7 miles of shoreline habitat
  - Cattle and gully exceptions

Conservation Easement from Montana de Oro To Fields Cove



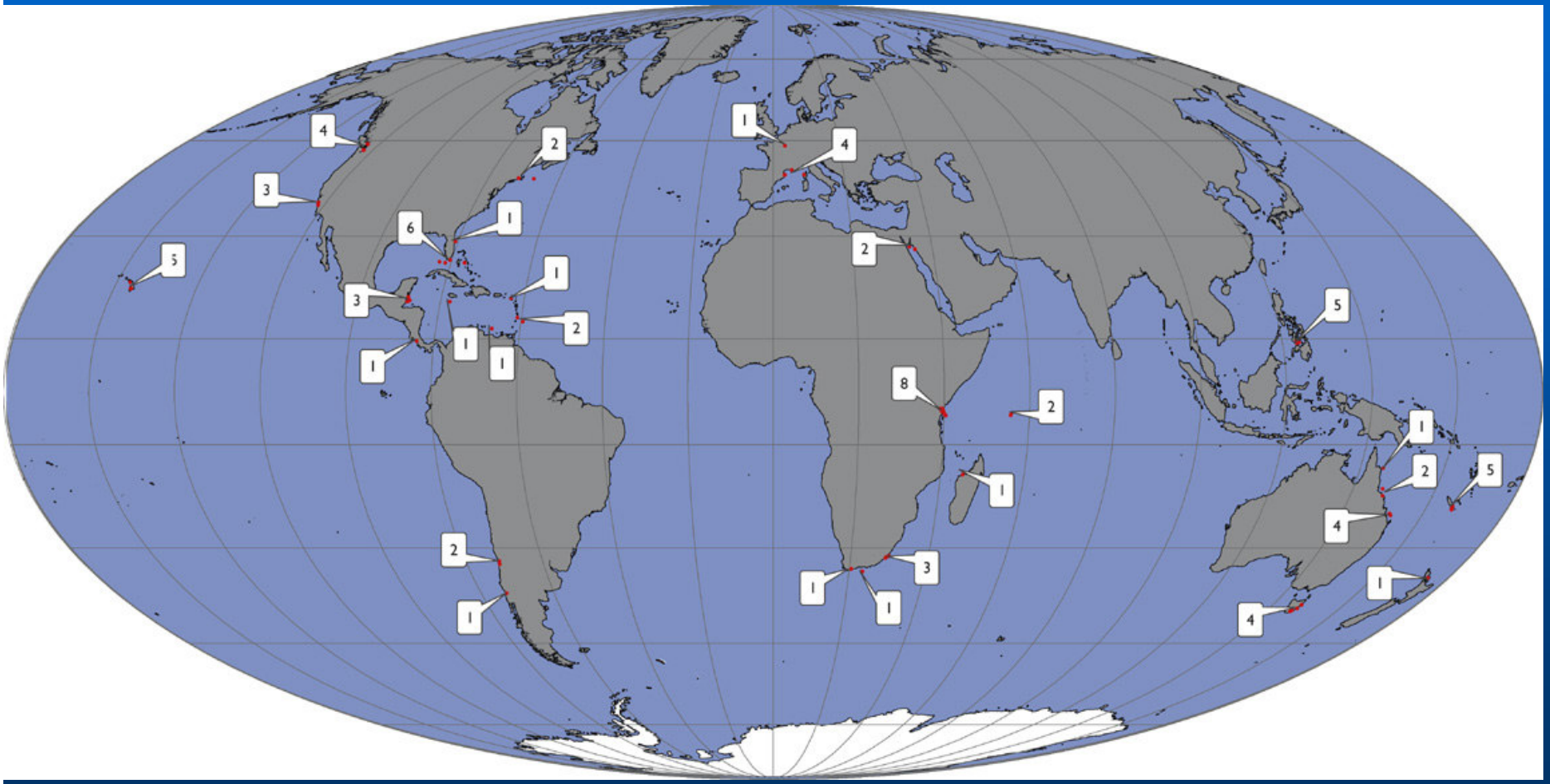
Coon Creek

5.7 miles of intertidal habitat

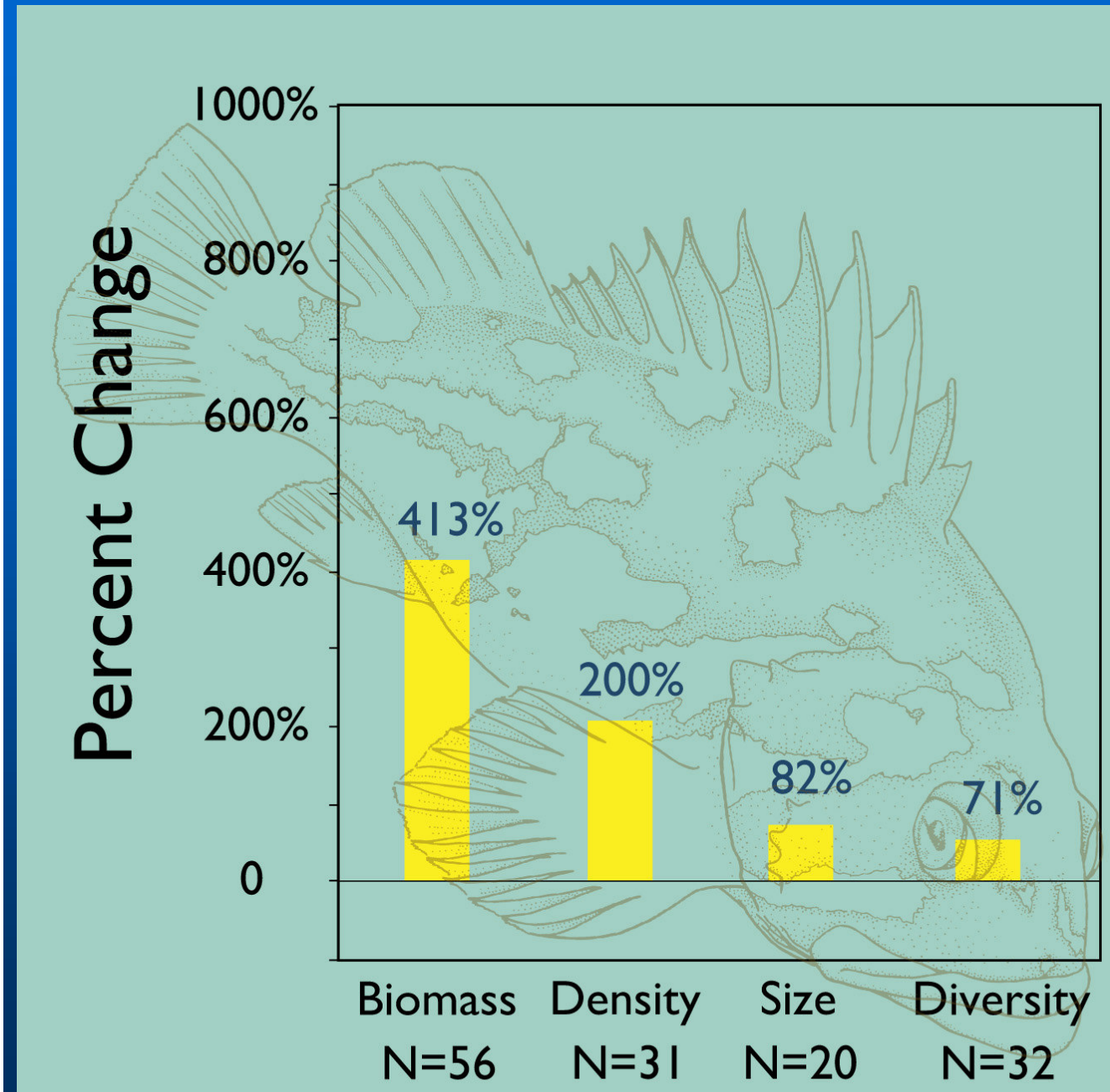
2013 acres

Field's Cove

80 Marine Reserves with Peer Reviewed Scientific Studies

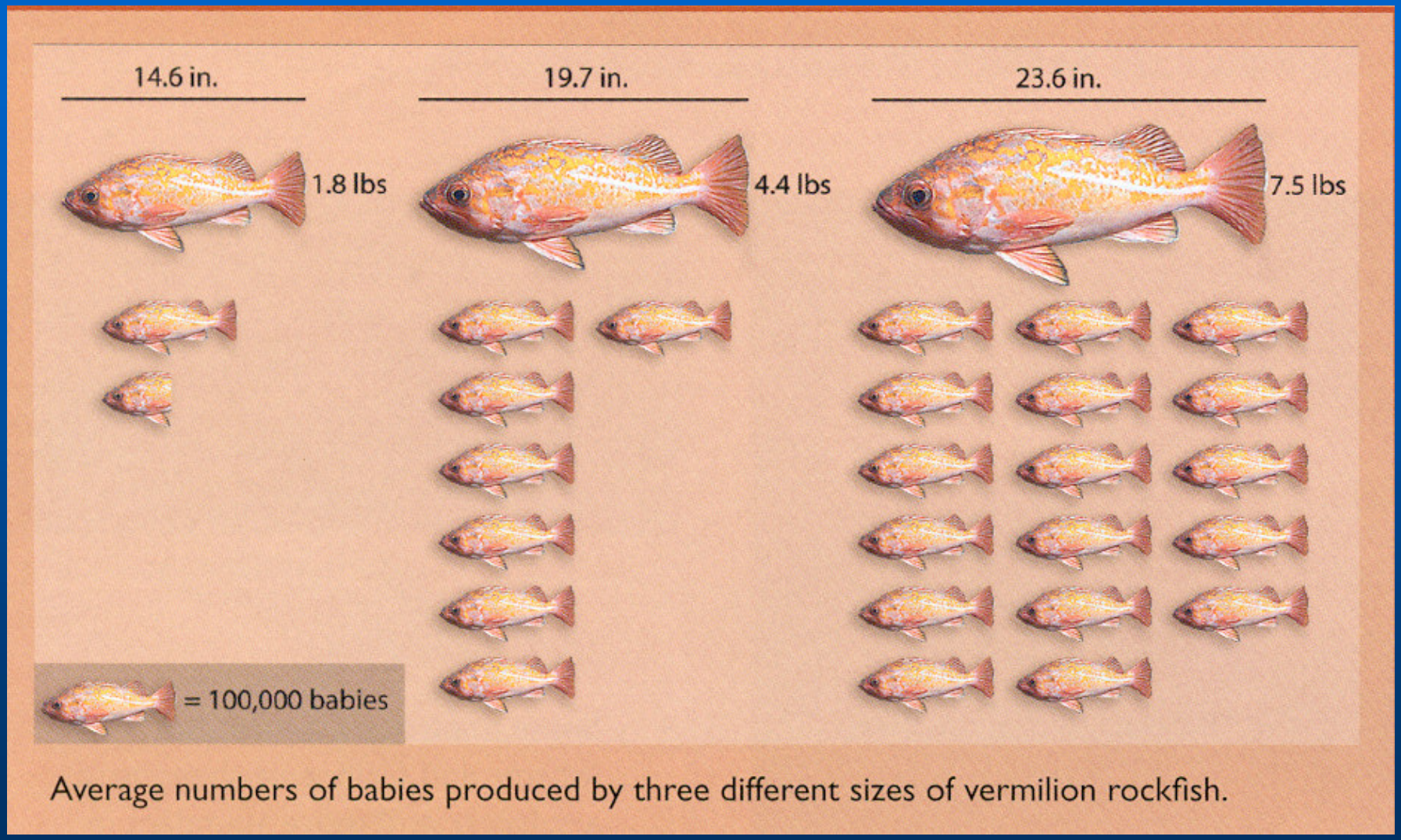


Range in size from less than 1 square mile to 400 square miles

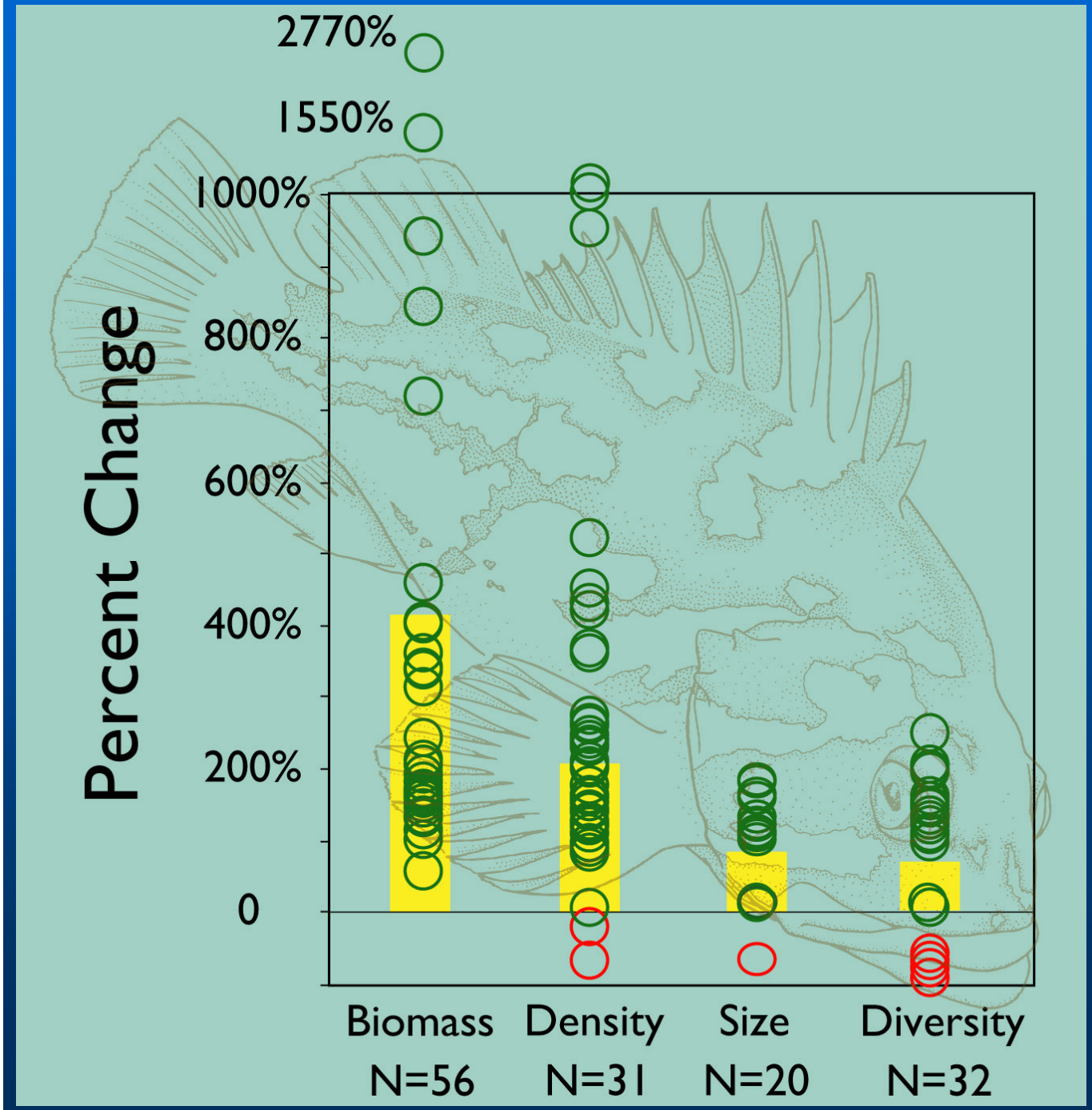


Large Effects Of Reserves Within Their Borders:

More biomass
More animals
Larger animals
More species

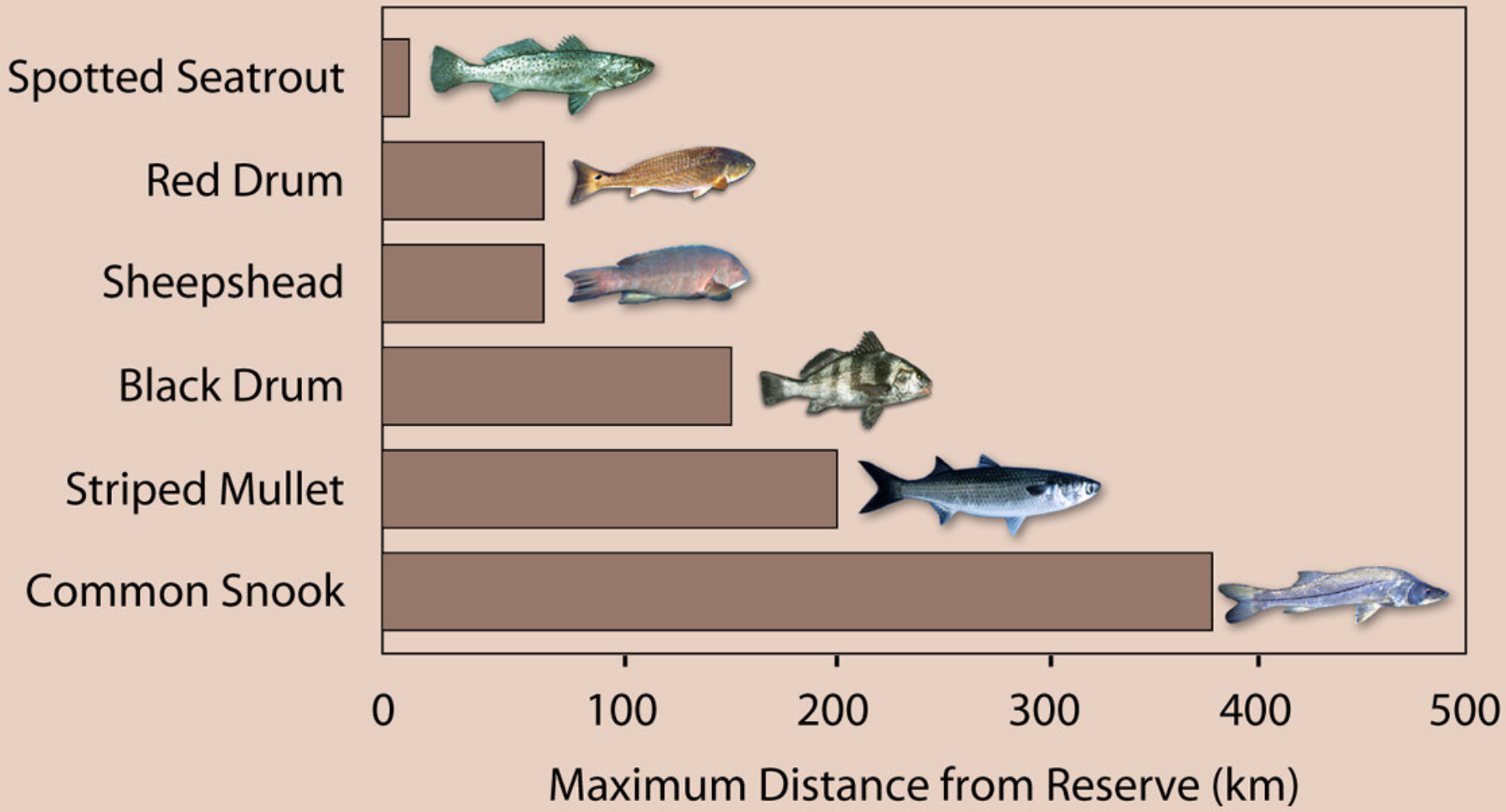


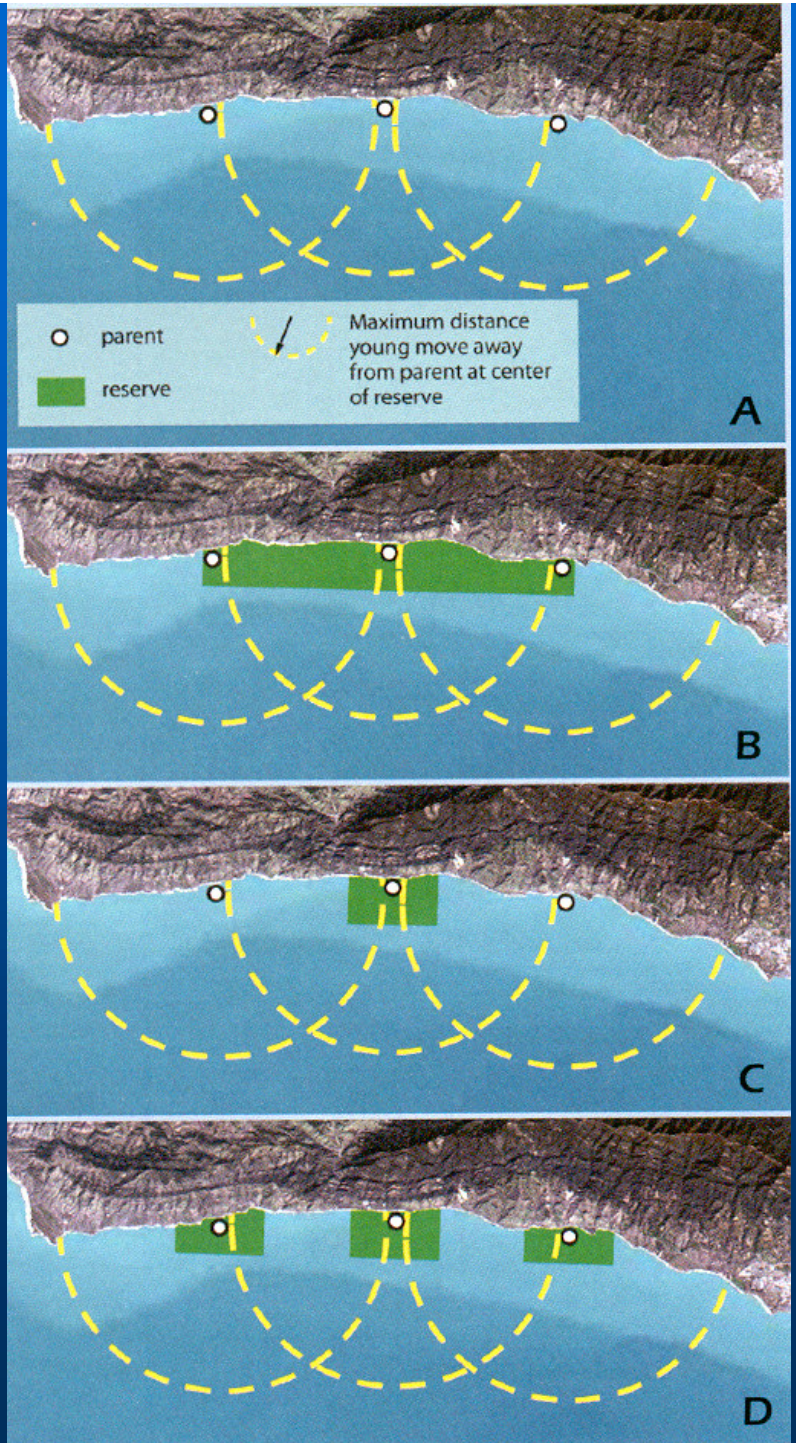
Average numbers of babies produced by three different sizes of vermilion rockfish.

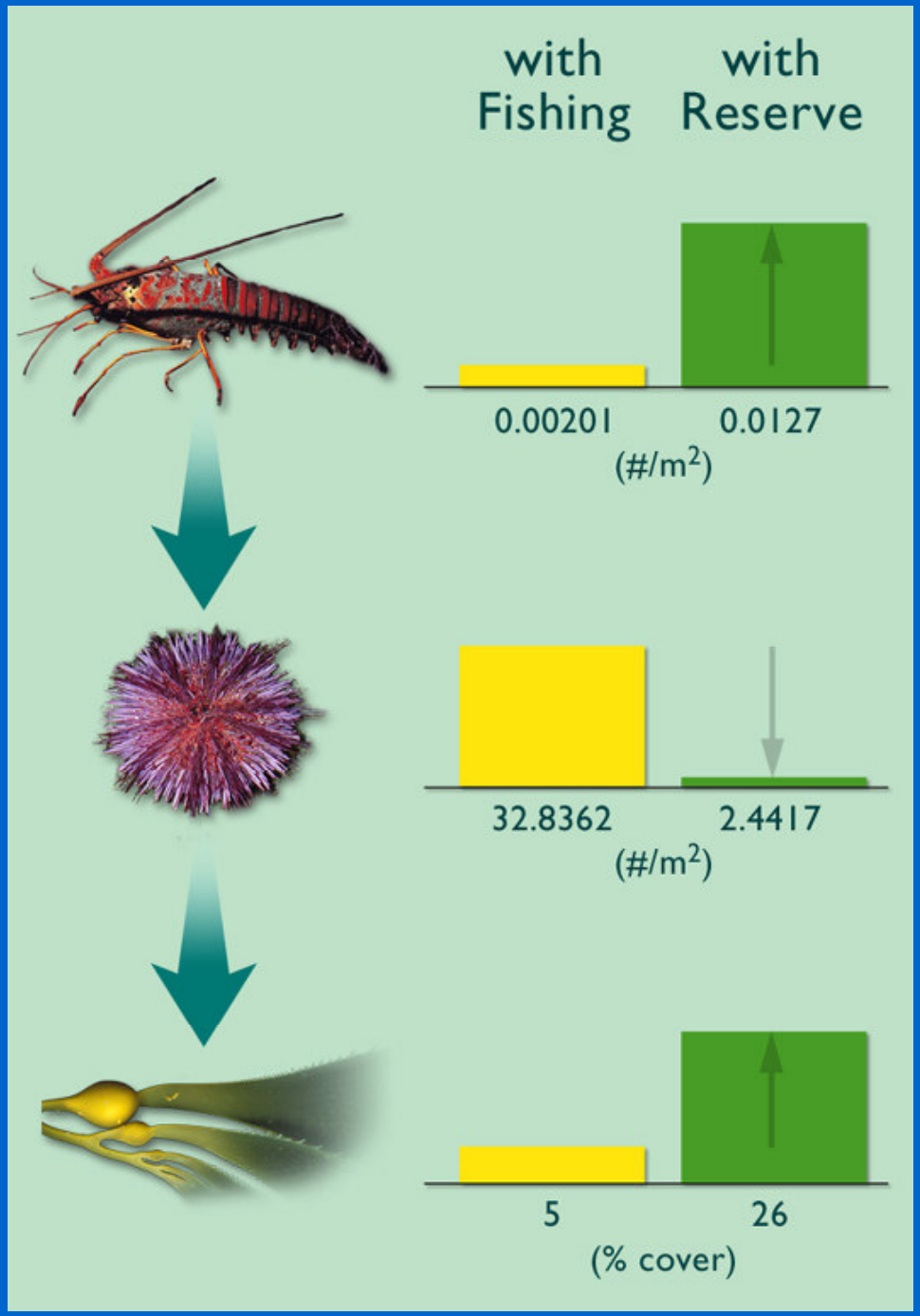


Positive changes occur more than 90% of the time

Fish Tagged in Reserve are Caught Outside the Reserve




parent
reserve
Maximum distance young move away from parent at center of reserve
A
B
C
D



Changes in the Anacapa Reserve

- **Ecological interactions are important**
- **Purple urchins rarer inside reserve than outside**
- **Urchin barrens have never occurred in the reserve**

Why Sample?

- Large Area
- Difficult to know the abundance of organisms exactly
- So, must estimate from sampling

Many potential SOURCES OF VARIATION

Sources of Variation

- Sampling “error” (variation among samples)
- Different DEPTH distributions
- Site to Site variation
- Seasonal variation
- Year to Year variation
- Longer-term environmental variation
- Impacts

Why Replicates are Needed?

To deal with Sources of Variation

- **Spatial coverage WITHIN Sites**
- **Spatial coverage BETWEEN Sites**
- **Coverage through TIME (seasons/years)**
- **“Control” vs “Impact”**

What is BACI Analysis?

BEFORE-AFTER-CONTROL-IMPACT

"Best approach available for separating spatial and temporal variation resulting from an impact" (PG&E, Tenera, 1997).

Idea Behind BACI

Major CAUSES OF VARIATION (storms, upwelling, El Nino, global warming, etc)

- **operate over a wide area**
- **have similar effects on "impact" and "control" sites**

BACI basics

- **Stations assigned to “Control “and “Impact” Groups**
- **Based on whether or not Temperature measurements at stations indicate warming from plume**
- **Uses** “Significance tests” **to determine if there are effects**

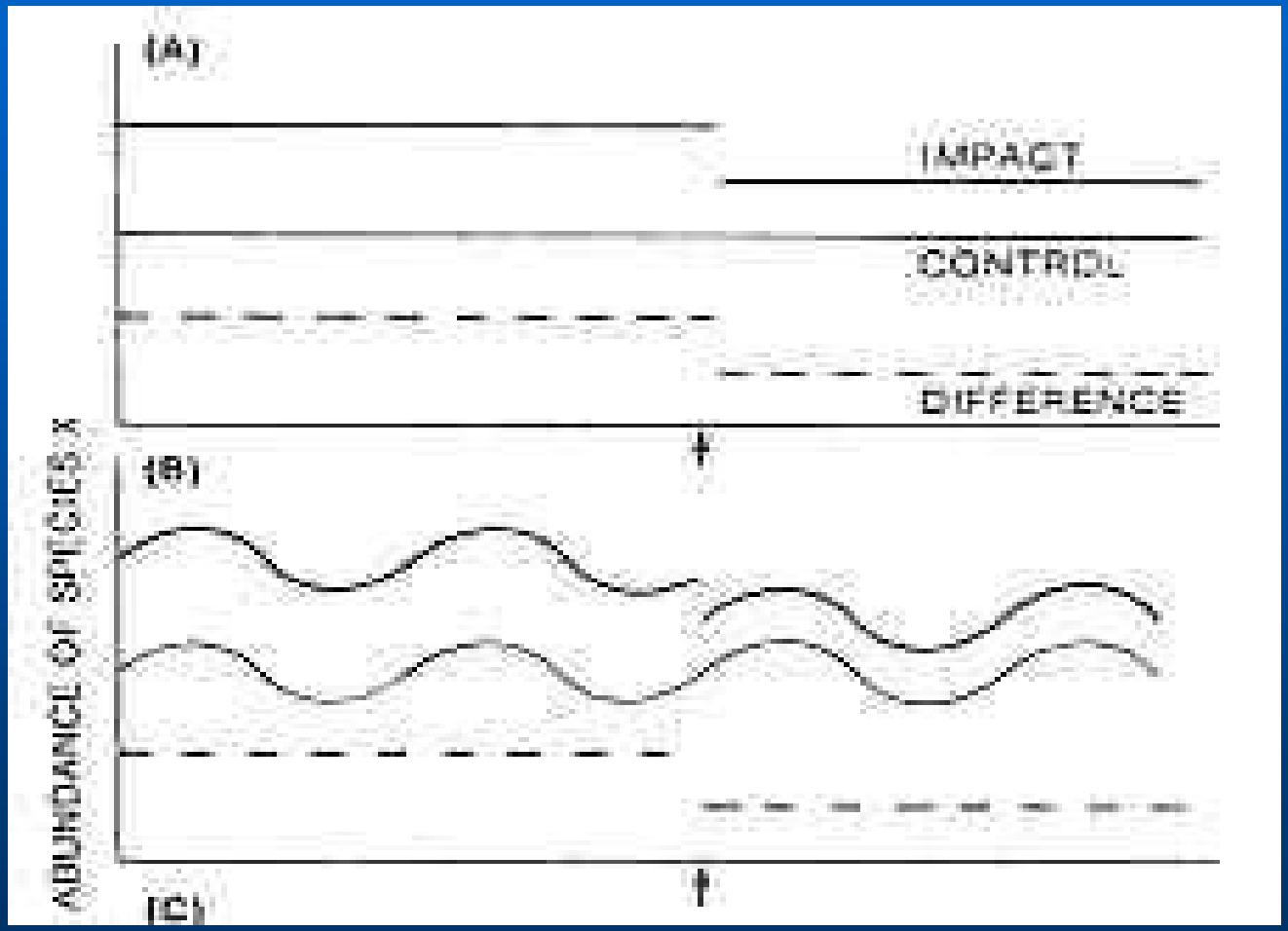
BACI has assumptions

Populations in Control and Impact areas

- have similar trends in abundance Before a disturbance
- changes must track one another

Altogether, 222/714 taxa tested (31%)

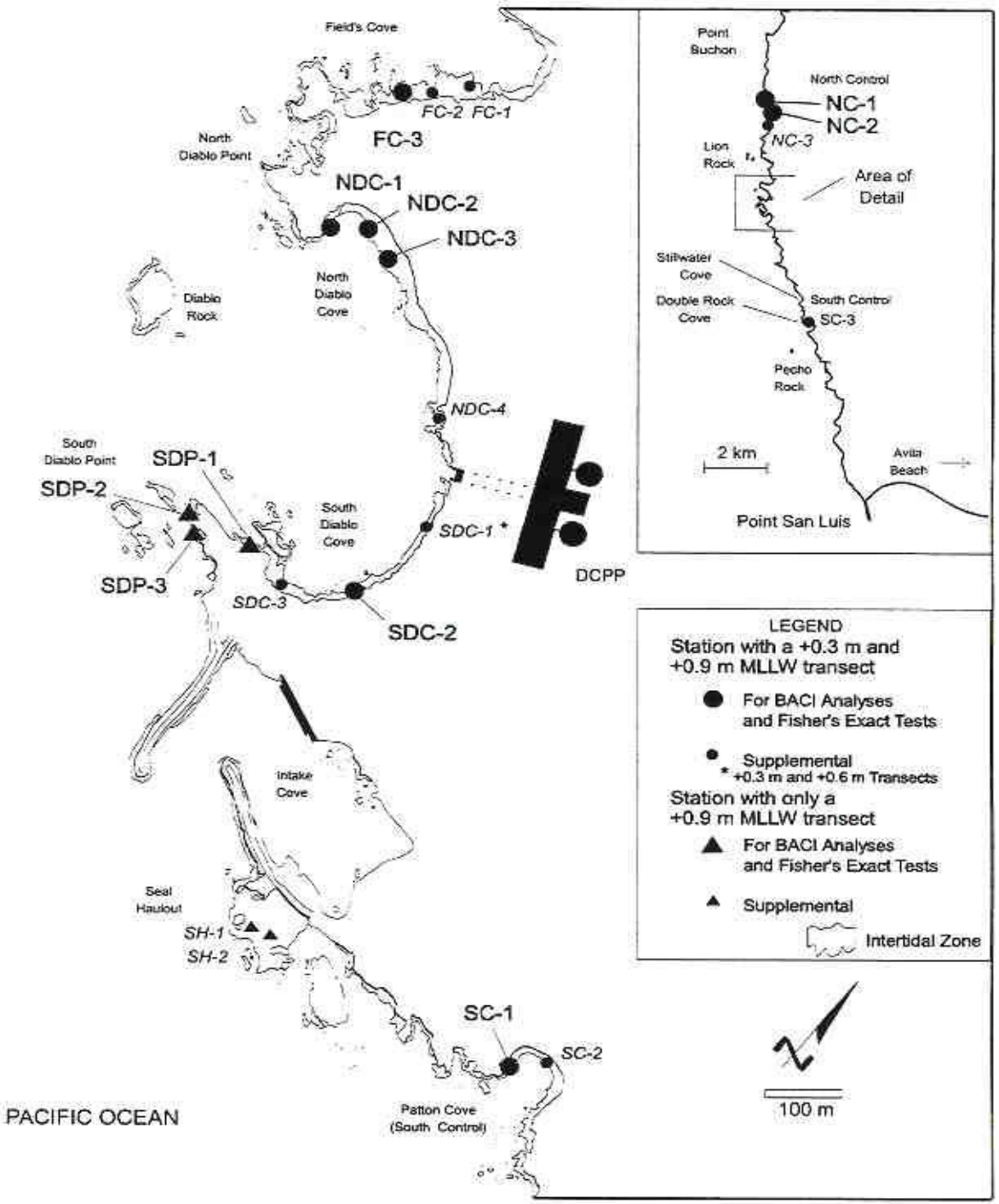
BACI (simplified)



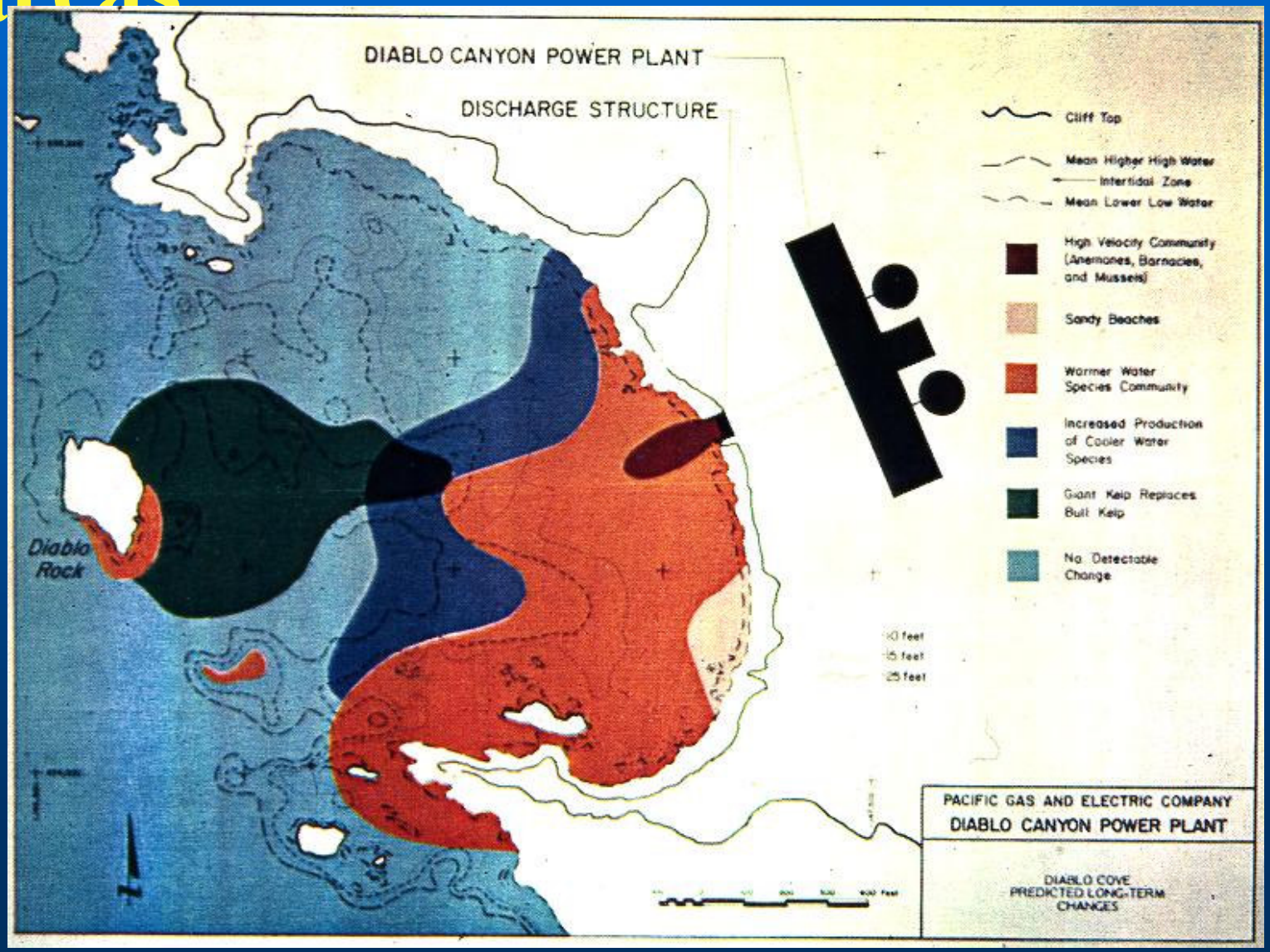
Before After

BACI Analysis

- **Concurrent sampling of “Impact” and “Control” sites**
- **Multiple Control Stations**
- **Multiple Impact Stations**
- **Compares average DIFFERENCES between** Impact **&** Control **stations** Before **&** After **power plant start-up**


Field's Cove
FC-2 FC-1
FC-3
North Diablo Point
NDC-1
NDC-2
NDC-3
Diablo Rock
North Diablo Cove
NDC-4
South Diablo Point
SDP-1
SDP-2
SDP-3
South Diablo Cove
SDC-1
SDC-3
SDC-2
DCPP
Intake Cove
Seal Haulout
SH-1
SH-2
SC-1
SC-2
Patton Cove (South Control)
PACIFIC OCEAN
Point Buchon
North Control
NC-1
NC-2
NC-3
Lion Rock
Area of Detail
Stillwater Cove
Double Rock Cove
South Control
SC-3
Pecho Rock
2 km
Avila Beach
Point San Luis
LEGEND
Station with a +0.3 m and +0.9 m MLLW transect
For BACI Analyses and Fisher's Exact Tests
Supplemental +0.3 m and +0.6 m Transects
Station with only a +0.9 m MLLW transect
For BACI Analyses and Fisher's Exact Tests
Supplemental
Intertidal Zone
100 m

Predicted intertidal impact areas



What are the CAUSES of Change?

Statistical "significance" tells us about DIFFERENCES

The CAUSES must be surmised

Some Causes of Change

Direct

- Thermal impact
- Scour

Indirect

- Competition
- Predation
- Reproductive changes
- Recruitment failure

Significance Tests

- **Rigorous way of determining if an ABUNDANCE VARIABLE is different between sampled groups:**

  DETECTING AN EFFECT

- Usually set at 5% or less ===>

  Probability of NO EFFECT is 5% or less

  OR, 95% chance of a REAL EFFECT

Significance levels

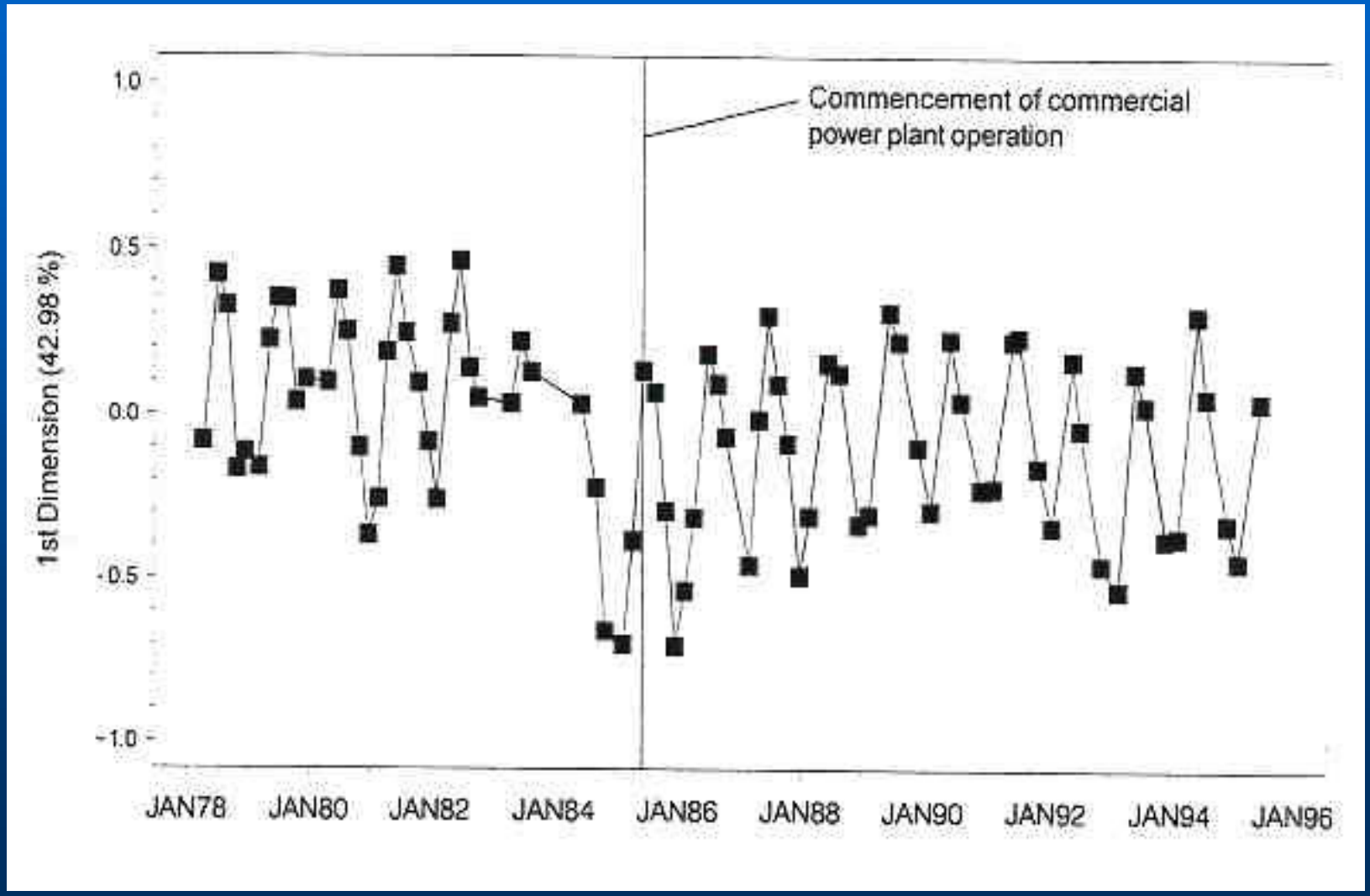
P-level	Frequency
0.001 (99.9%)	14
0.01 (99%)	2
0.05 (95%)	3
0.1 (90%)	4

Community-level changes

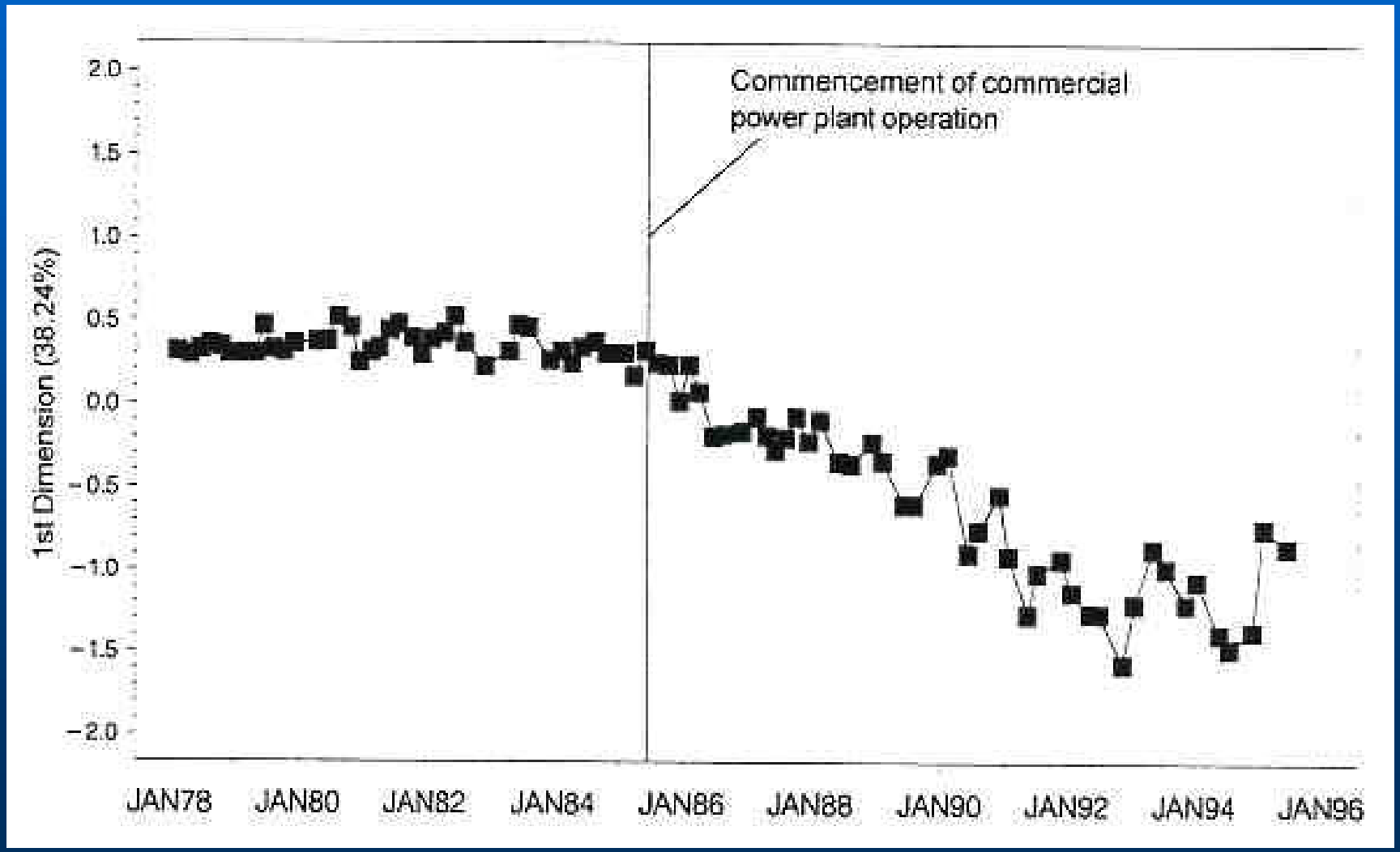
Correspondence Analysis

- Multi-variate
- To Examine & Describe changes over time
- Temporal Gradient of Change

Correspondence Analysis
(Control [NC-1, -2, SC-1] algae, +0.3m level)

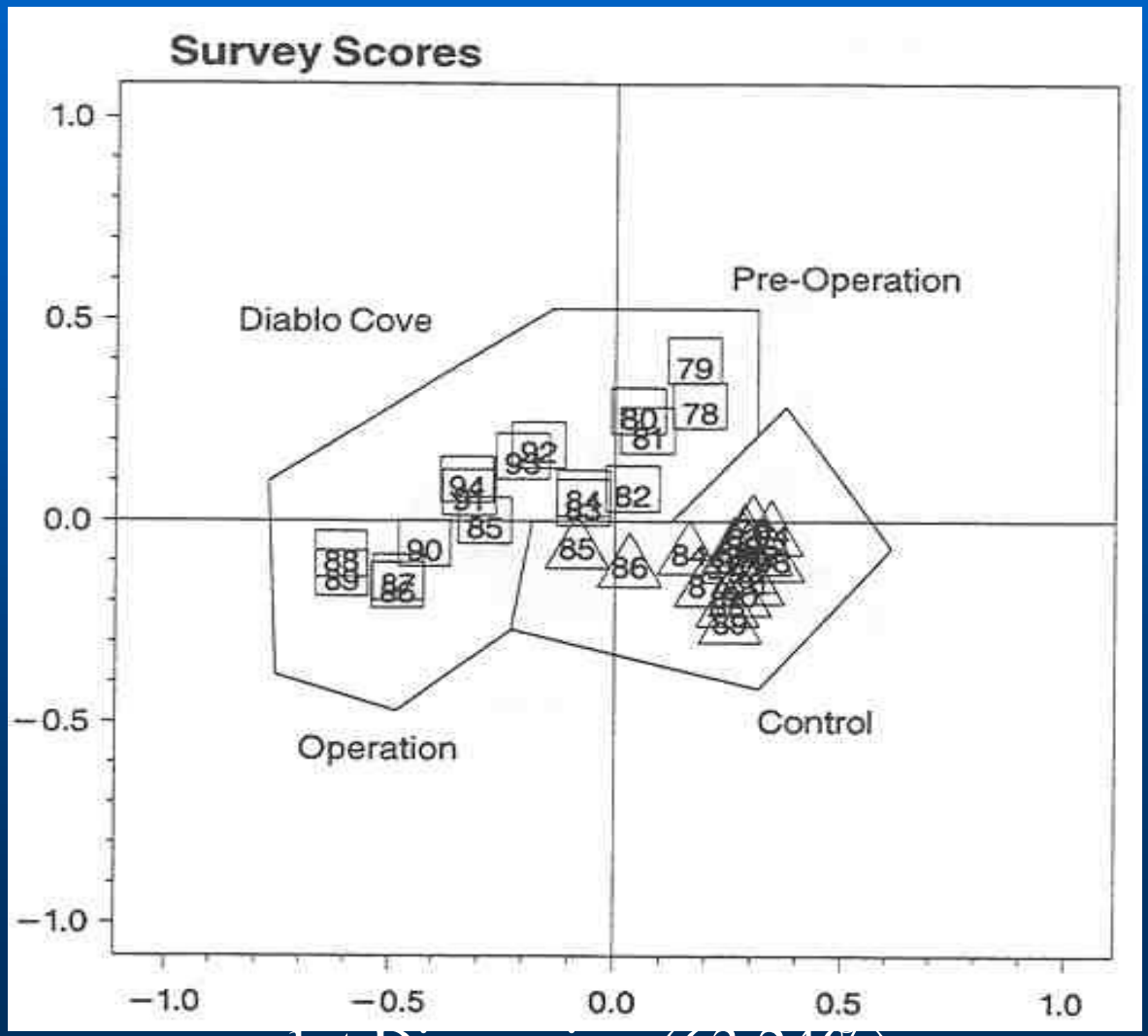


Correspondence Analysis
(NDC-3, algae, +0.3m tidal level)



Correspondence Analysis

(Diablo Cove & Control, algae & inverts, +0.3m)



Status Report: Diablo Canyon Nuclear Power Plant

- Background Information
- Thermal Effects Summary
- Entrainment Study Update
- Conclusion
  - Regional Board Options
  - Recommendation

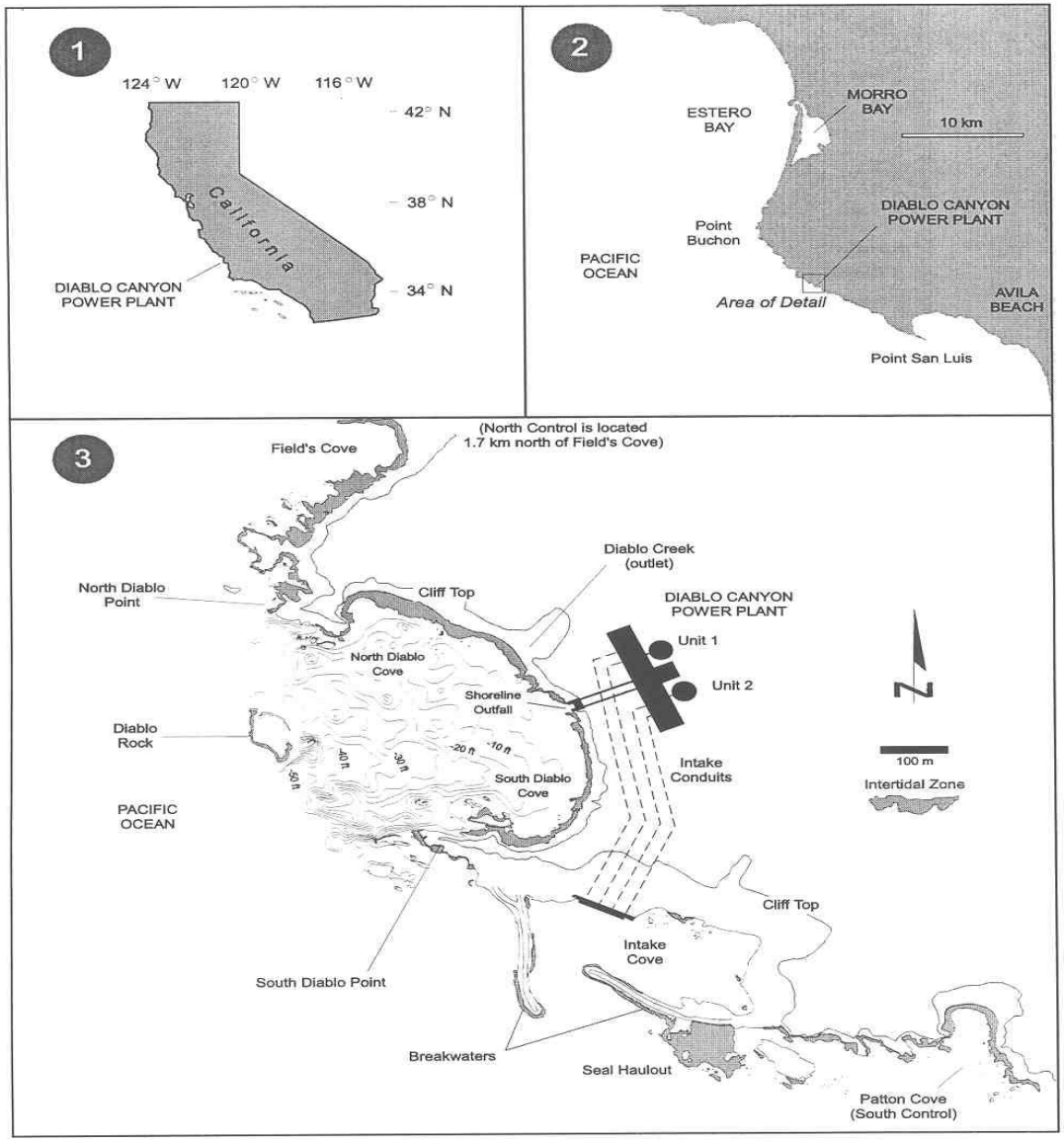
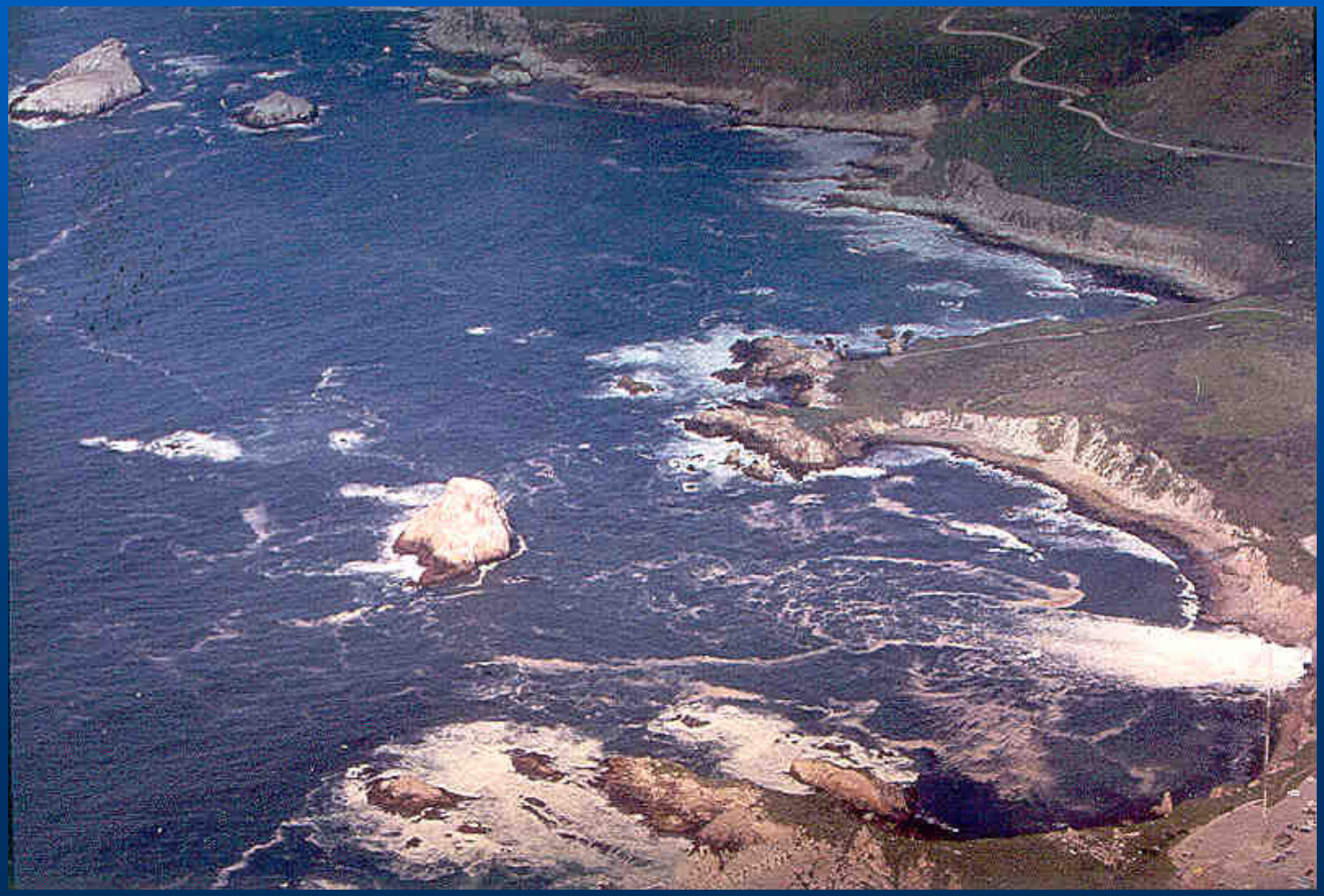


Figure S-1. Location of Diablo Canyon Power Plant.

Diablo Cove and Fields Cove



Diablo Cove and Intake Cove

Status Report:
Diablo Canyon Nuclear Power Plant

Background….

- 1966: PG&E signed an Agreement with State of CA
- 1969: First discharge Permit issued
- 1970 through early 1980's: Many

Background Info continued...

- 1973: Atomic Energy Commission published its Final Environmental Statement-- harmful effects identified through monitoring programs must be remedied

- 1975: State Board adopted the Thermal Plan, requiring protection of beneficial uses

Background Info continued...

- 1981: Regional Board prepared draft permit that prohibits the discharge of heat
- PG&E asserted that for most indigenous species, there will be no detectable effects from the thermal discharge

Background Info continued...

- 1982: Regional Board adopted a permit prohibiting the discharge of heat
- Permit also required submittal of thermal effects predictions
- Permit also required submittal of an alternatives analyses

Background Info continued...

- 1982: PG&E appealed the NPDES Permit prohibiting discharge of heat
- PG&E again asserted that “for most indigenous species in Diablo Cove, there will be no detectable effects from the thermal discharge”

Background Info continued...

- May 14, 1982: PG&E presented its predictions to the Regional Board
- Overall prediction was that certain species would be “at risk” in part of Diablo Cove during the warm season
- Effects expected to be “much much less” than presented
- Few impacts to intertidal zone in Diablo Cove

Background Info continued...

- 1988: PG&E submitted a “final” 316b (entrainment/impingement) report
- 1988: PG&E submitted a “final” thermal effects report
- Regional Board reduced monitoring, then re-instates monitoring per Fish and Game request

Background Info continued...

- 1995: Regional Board received information alleging PG&E withheld certain data from the 1988 316b report
- 1995: Regional Board asked the Attorney General to investigate allegations
- February 1995: Regional Board reduced monitoring and directed staff to begin multi agency workgroup process (thermal and entrainment)

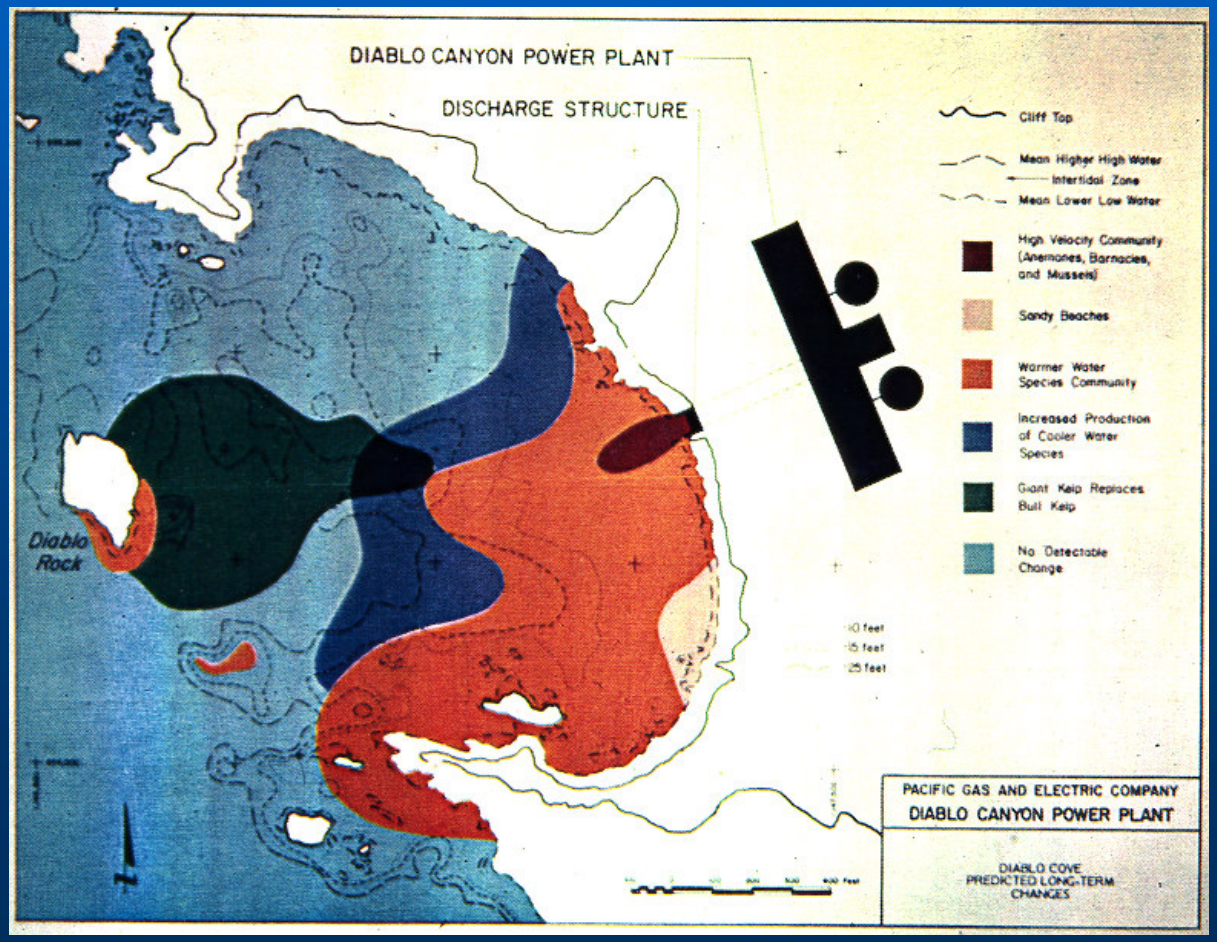
Background Info continued...

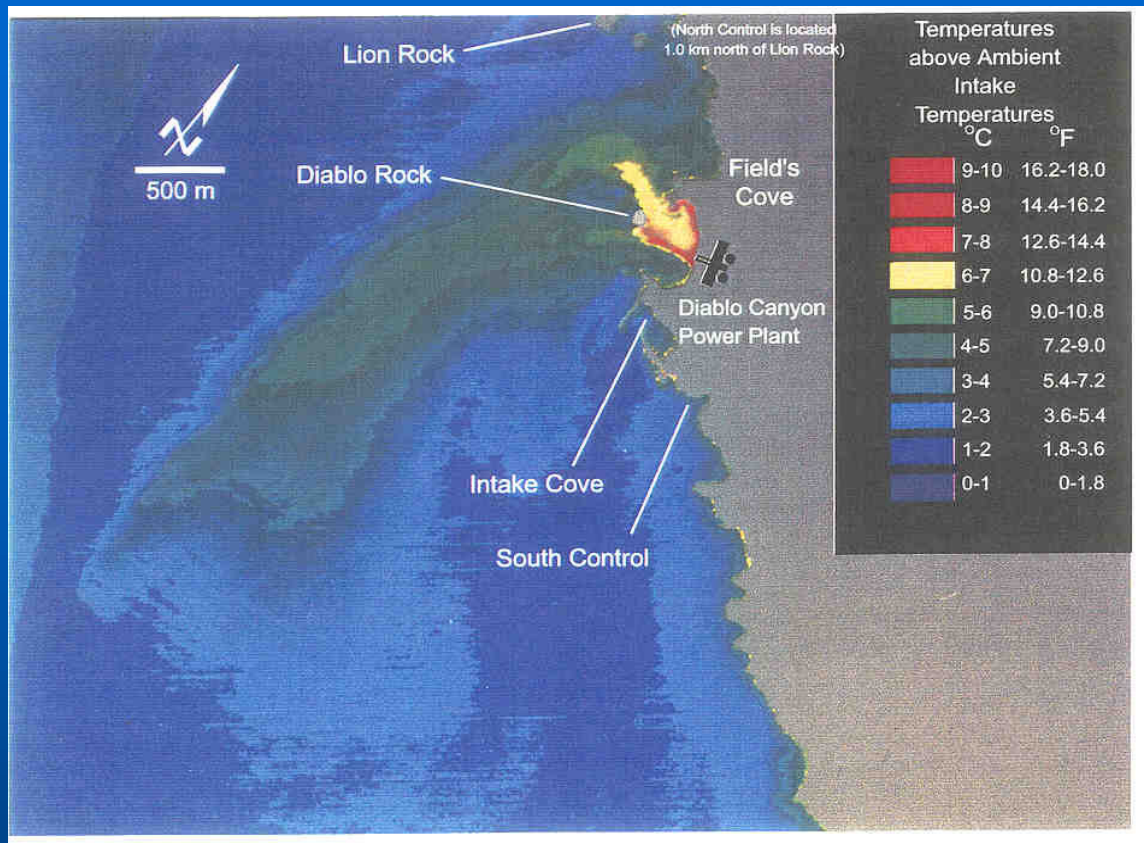
- 1997: PG&E agreed to settlement of $14.4 million regarding withholding of data from 1988 316b report
- December 1997: PG&E submitted comprehensive thermal effects report
- February 1998: Staff advised PG&E that impacts were not protective of beneficial uses, suggested land preservation

Thermal Impacts Summary

- Purpose of a receiving water monitoring program is to detect changes relative to control stations
- PG&E and Regional Board and Fish and Game agreed to the monitoring program at Diablo
- Monitoring program has detected large biological changes relative to control stations

PG&E's "long-term" thermal effects predictions (1982)





Test TV-7
Date: June 11, 1986
Time: 18:20 PDT

Unit	Discharge Temp° C	Cooling Water Flow (cfs)	Reactor Power (%)
1	21.4	2000	100
2	19.5	2000	70

Intake Temp: 10.9° C
Tide: 2.8 ft (MLLW)
Wind: 17.5 mph from 313° (true)
Offshore Currents: 19.4 ft/min. from 135°
Sig. Wave Ht.: 92 cm @ 11 sec from 270°
Air Temperature: 15.5° C

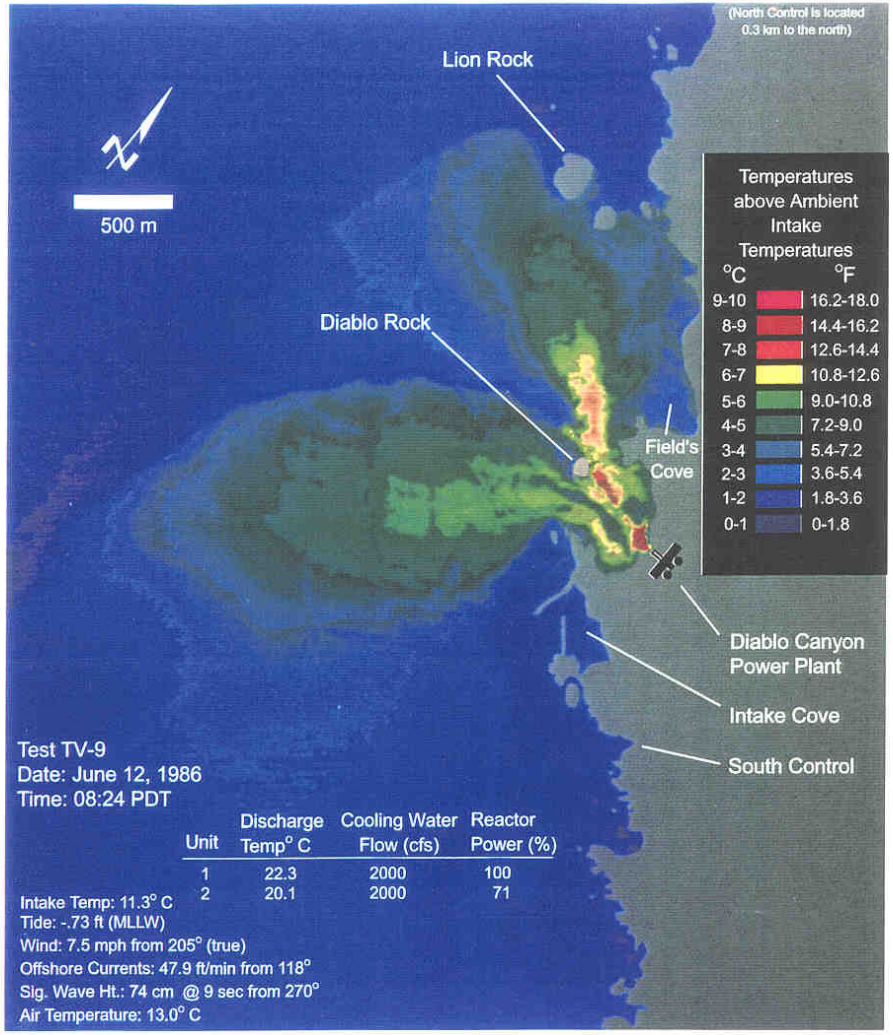
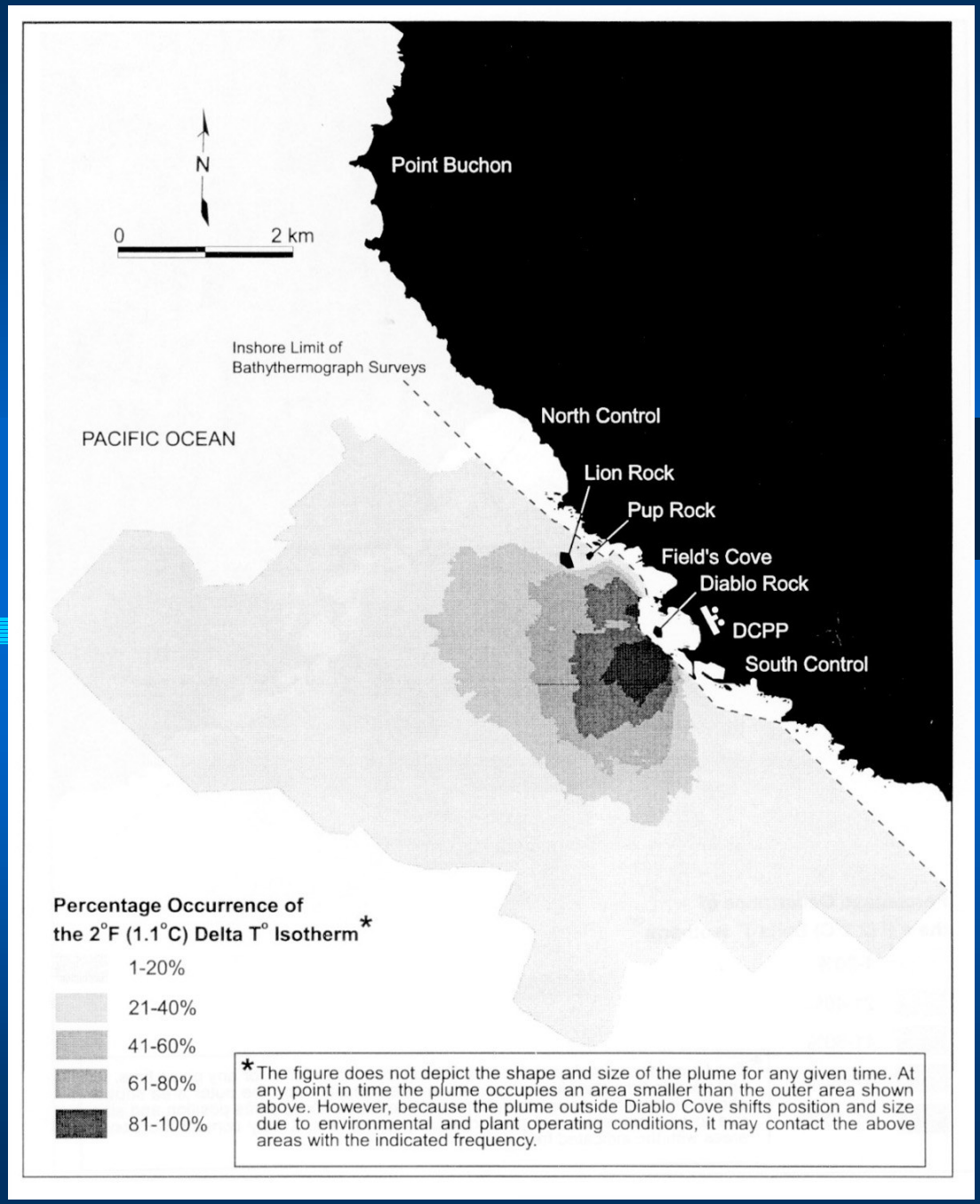


Figure 2-6. Surface thermal plume isotherms (°C) above ambient intake temperatures measured on June 12, 1986. Ambient intake temperatures (of water drawn from -10 m [-32 ft] MLLW) were 1-2°C cooler than ambient surface temperatures. Therefore, the ambient intake temperature color (0-1°C) does not appear in the plume figure.


N
0
2 km
Point Buchon
Inshore Limit of
Bathythermograph Surveys
PACIFIC OCEAN
North Control
Lion Rock
Pup Rock
Field's Cove
Diablo Rock
DCPP
South Control
Percentage Occurrence of
the 2°F (1.1°C) Delta T° Isotherm*
1-20%
21-40%
41-60%
61-80%
81-100%
*The figure does not depict the shape and size of the plume for any given time. At any point in time the plume occupies an area smaller than the outer area shown above. However, because the plume outside Diablo Cove shifts position and size due to environmental and plant operating conditions, it may contact the above areas with the indicated frequency.

NPDES Permit Requirements

Waste discharges shall not individually or collectively cause:

- Objectionable aquatic growth or degradation of indigenous biota
- Temperature of the receiving water to adversely affect beneficial uses
- Degradation of marine communities, including vertebrate, invertebrate, and plant species

1966 Agreement Between PG&E and State of CA

- Agreement States

  In the event that adverse effects accrue to aquatic life or recreation uses due to plant construction or operation, Pacific will provide reasonable mitigation for losses incurred, provided such mitigation will not interfere with the construction or operation of the plant unless otherwise agreed…

1973 Environmental Statement

Atomic Energy Commission

States:

If harmful effects or evidence of irreversible damage are detected by the monitoring programs, the applicant shall provide an analysis of the problem and implement a program of remedial action to be taken promptly to eliminate or significantly reduce the detrimental effects or damage.

Recent History/Current Status

- February 1988: Staff informs PG&E that thermal impacts show non-compliance
- 1998 to September 1999: Discussions regarding resolution via land preservation continued
- September 1999: Board directed staff to present options for expediting resolution, including enforcement options.

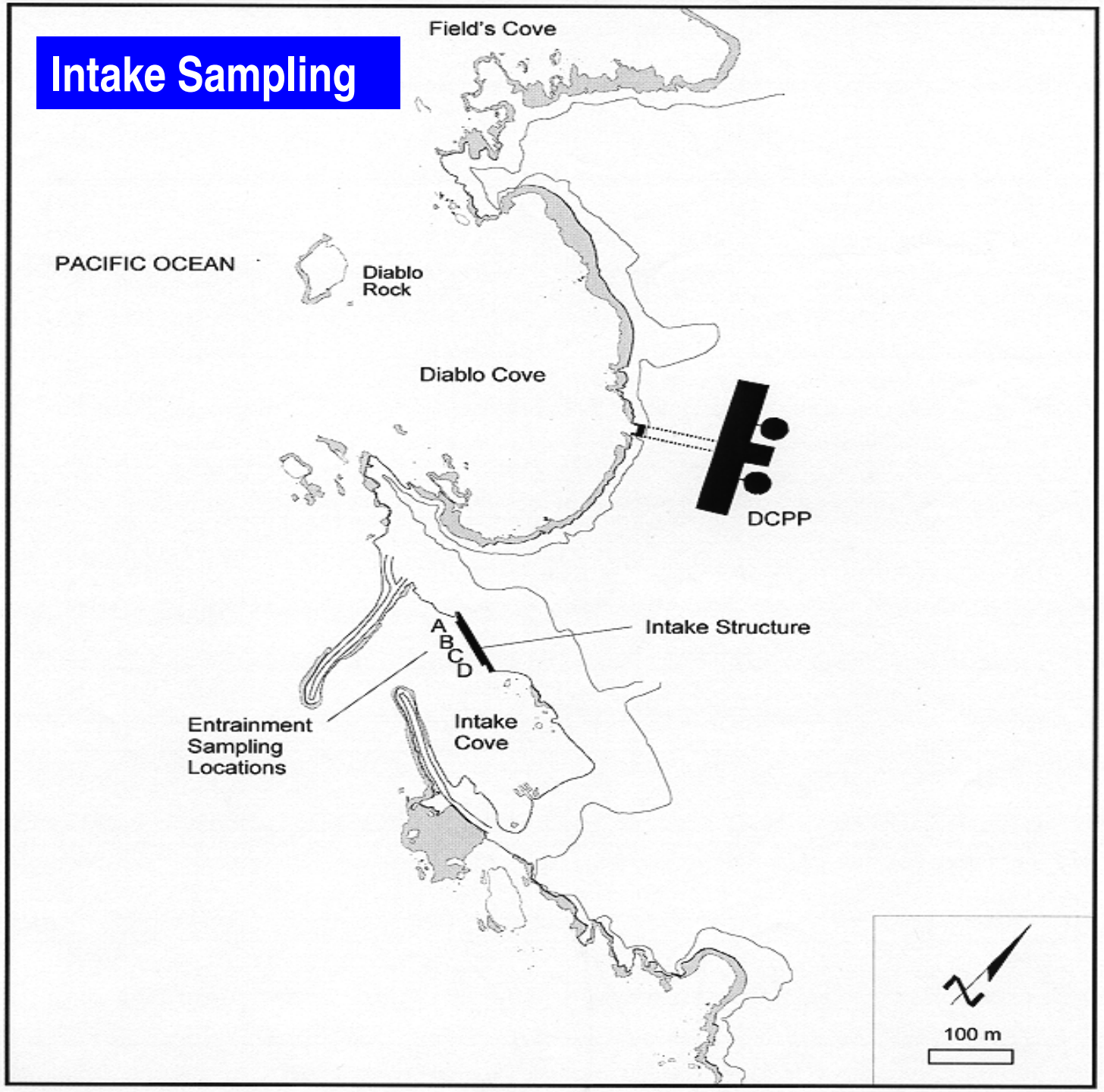
Recent History/Current Status Continued...

- Thermal Impacts
  - November 1999: Board directed staff to pursue enforcement regarding thermal effects
  - Staff has prepared a draft Cease and Desist Order for consideration on March 30, 2000
- Entrainment Study
  - Final entrainment report due on March 1, 2000

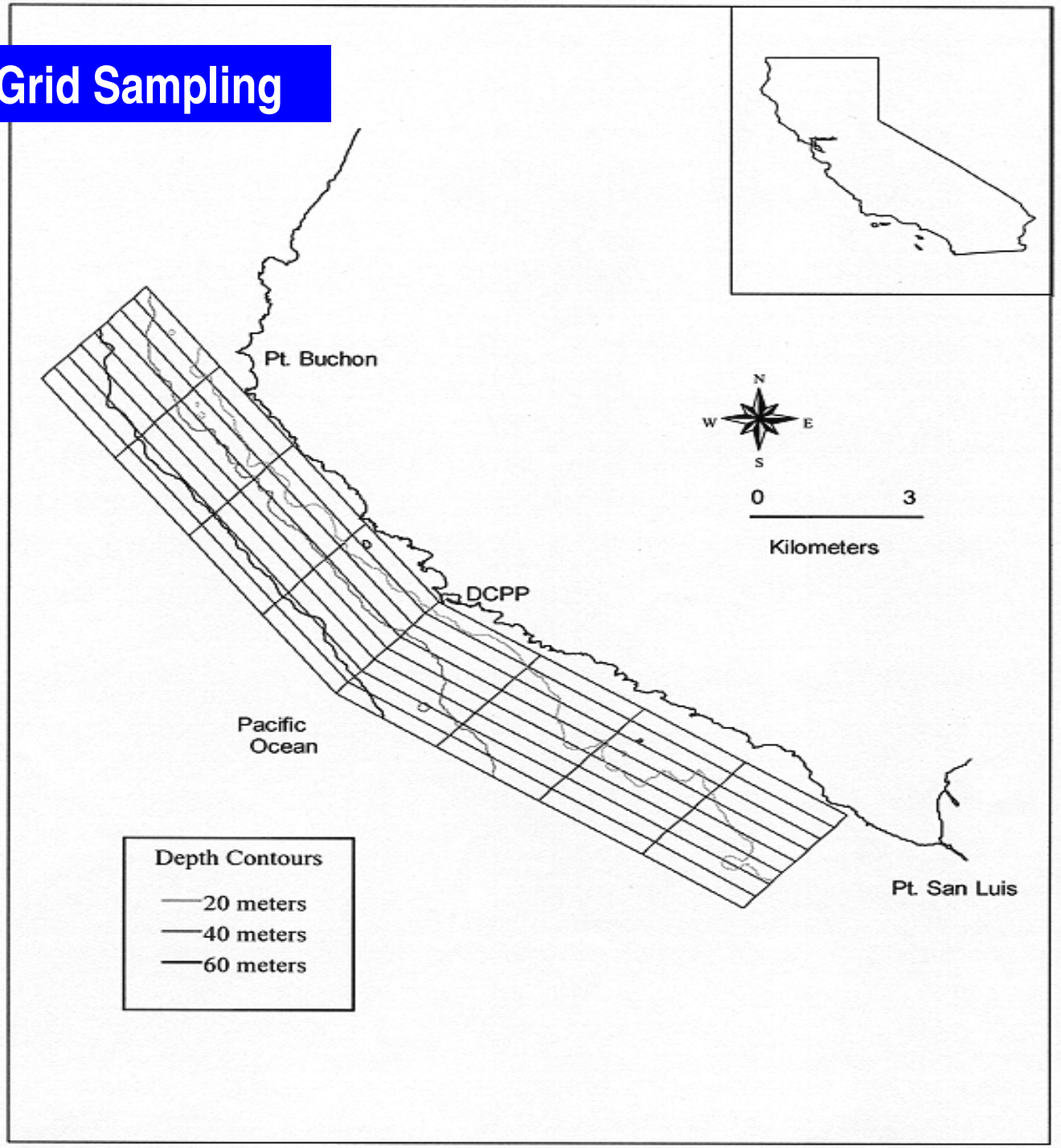
Entrainment Study Update

- Purpose of study is to estimate amount of larvae entrained for certain fish and crab species, and estimate resource impacts
- Intake Sampling and offshore grid sampling
- Models: Adult Equivalent Loss, Fecundity Hindcasting, Empirical Transport

Intake Sampling



Offshore Grid Sampling



Entrainment Study Update
Continued...

- Draft report submitted December 10, 1999
- Impacts to offshore species expected to be relatively minor
- Impacts to nearshore species may be significant (large fraction of available

Conclusion

- Distribution of thermal plume
- Spatial extent of impacts
- Magnitude of taxa changes
- Permit requirements
- Non-compliance with Permit

NPDES Permit Requirements Again…

Waste discharges shall not individually or collectively cause:

- Objectionable aquatic growth or degradation of indigenous biota
- Temperature of the receiving water to adversely affect beneficial uses
- Degradation of marine communities, including vertebrate, invertebrate, and plant species

Regional Board Options

- Proceed with Cease and Desist Order
  - Conduct Hearing on March 30, 2000
- Draft an Administrative Civil Liability Complaint

Recommendation

- Proceed with Evidentiary Hearing on March 30, 2000 to consider Cease and Desist Order
  - Close Hearing, deliberate, vote
  - Close Hearing, schedule future vote
- Staff presents entrainment results on May 19, 2000
- Final recommendations regarding overall solution presented on July 14, 2000
  - New NPDES Permit including thermal and entrainment resolution in late 2000

END

February 9, 1982
Petition filed by PG&E

While bull kelp (Nereocystis) may be replaced with another kelp (Macrocystis), which is an equivalent habitat former, the overall prediction is that for most indigenous species in Diablo Cove, there will be no detectable effects from the thermal discharge.

State Board Order WQ 83-1

- Includes PG&Es predictions for several species
- Based on predictions, the discharge will significantly alter water quality in Diablo Cove
- Actual impacts are greater than predictions included in Order WQ 83-1

State Board Order WQ 83-1 Continued...

- Several of the provisions of Order No. 82-24 should prevent or alleviate any long-term damage to Diablo Cove. These include Receiving Water Limitation C.1. which mandates that "[e]levated temperature wastes shall not adversely affect beneficial uses" and Provision D.7.(a), which requires PG&E to submit a thermal effects study to determine whether the thermal discharge adequately protects beneficial uses.

State Board Order WQ 83-1 Continued...

- The permit is also subject to a condition authorizing modification or termination of the permit for cause. Should the thermal effects study reveal that the present thermal limits contained in Order No. 82-24 are inadequate to protect beneficial uses, the Regional Board has ample authority to modify or revoke the permit.

State Board Order WQ 83-1 Continued

... Further, the [State] Board believes that the thermal effects study required under Order No. 82-24 and related monitoring will provide needed data on the actual thermal impacts of the discharge. It is appropriate for the Regional Board to wait until this data is available before determining whether the impacts are unreasonable, and whether remedial action should be undertaken by the company.

Regional Board NPDES Permits for Diablo Canyon

1982, 1985, and 1990 Diablo Canyon NPDES Permits State:

Waste discharges shall not individually or collectively cause…

Degradation of marine communities, including vertebrate, invertebrate, and plant species.

INTERTIDAL ALGAE

mean %cover over all impact stations (2.3 miles of habitat)

- Fourteen species decreased between 50% and 99%
- Five of the fourteen species decreased at least 80%
- Two of the fourteen species decreased at least 90%
- Total algal cover decreased 57% relative to controls (0.9m stations)
- Bare rock increased 47% in Field's Cove relative to controls (0.9m stations)

September 18, 1981 Letter From PG&E to the Regional Board

- **The only beneficial use likely to be effected by the thermal discharge is the marine habitat. Some changes to the marine community are likely to occur within** part of Diablo Cove, but these changes are not likely to result in an adverse impact to the cove's marine habitat or its use. **The most noticeable effect is likely to be the replacement of bull kelp (Nereocystis with another kelp (Macrocystis). This kelp is an equivalent habitat former**. The overall prediction is that for most indigenous species, there will be no detectable effects

NPDES Permit Requirements continued...

Waste discharges shall not individually or collectively cause:

– Degradation of marine communities, including vertebrate, invertebrate, and plant species